CAE 331/513
Building Science
Fall 2013

Lecture 1: August 19, 2013
Introduction to Building Science

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

www.built-envi.com

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Objectives for today's lecture

- Introduce myself
- Introduce course topics
- Introduce yourselves
- Discuss syllabus
  - Course information, outline, schedule, ground rules
  - Why are we all here?
- Introduce fundamentals of building science
- Review of prerequisite requirements

About me

- B.S.E., Civil Engineering
  - Tennessee Tech University, 2007
- M.S.E., Environmental and Water Resources Engineering
  - The University of Texas at Austin, 2009
  - Thesis: "Energy implications of filtration in residential and light-commercial buildings"
- Ph.D., Civil Engineering
  - The University of Texas at Austin, 2012
  - Dissertation: "Characterizing the impacts of air-conditioning systems, filters, and building envelopes on exposures to indoor pollutants and energy consumption in residential and light-commercial buildings"
- Work experience relevant to this course
  - NSF IGERT Fellow in Indoor Environmental Science in Engineering
  - Energy intern at Southface Energy Institute in Atlanta, GA

Course information

CAE 331/513: Building Science

Course Unique Number(s)

- CAE 331 Section 1: 10405 (undergraduate)
- CAE 513 Section 1: 15258 (graduate)

Classroom and Meeting Time

- Engineering 1, Room 124
- Mondays 5:00 PM – 7:40 PM

Prerequisites

- CAE 209 Thermal Fluids Engineering II, MMAE 322 Heat and Mass Transfer, or CHE 302 Heat and Mass Transfer Operations

Course information

Course Catalog Description

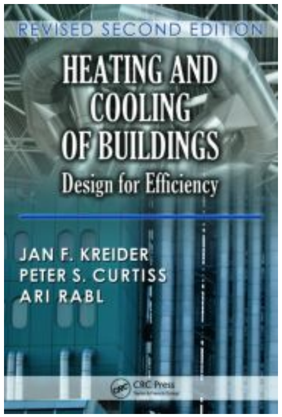
- Study of the physical interaction of climate (humidity, temperature, wind, sun, rain, snow, etc.) and buildings. Topics include psychrometrics, indoor air quality, indoor thermal comfort, heat transfer, air infiltration, solar insolation, and heating and cooling load calculation.

Course objectives

To introduce students to physical phenomena that affect building design and performance. By taking this course students will be able to:

1. Describe the role of building components and building environmental systems in energy consumption, peak electricity demand, thermal comfort, and human exposures to pollutants.
2. Describe the role of buildings and environmental systems in building design and construction.
3. Describe and quantify fundamental heat and mass transfer processes in buildings, including conduction, convection, radiation, thermodynamics, fluid flow, and mass balances.
4. Calculate heating, ventilating, and air-conditioning sensible and latent loads in a variety of building types.
5. Understand types of HVAC equipment for residential and commercial construction.
6. Describe and perform basic building diagnostic field tests (e.g., blower door tests).
7. Critically analyze claims about building components and environmental systems from product manufacturers, contractors, and building designers.

Textbook



Heating and Cooling of Buildings: Design for Efficiency

Kreider, J.F., Curtiss, P.S., and Rabl, A. 2010

CRC Press, Taylor & Francis Group.

ISBN: 978-1-4398-1151-1.

http://www.crcpress.com/product/isbn/9781439811511

- *The bookstore should have some copies*
- *There are also used copies on Amazon*

Additional references

- I will also draw on several other references in this course:
  - No need to purchase these, although I highly recommend purchasing the ASHRAE Handbook of Fundamentals
    - Relatively cheap for student members

ASHRAE 2013. *Handbook of Fundamentals.* American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

ASHRAE 90.1-2010. *Energy Standard for Buildings Except Low-Rise Residential Buildings.*

Janis, R.R. and Tao, W.K.Y. 2009. *Mechanical and Electrical Systems in Buildings*. Pearson Prentice Hall. ISBN: 978-0-13-513013-1.

Kuehn, T.H., Ramsey, J.W., and Threlkeld, J.L. 1998. *Thermal Environmental Engineering*. Prentice Hall. ISBN: 0-13-917220-3.

McQuiston, F.C., Parker, J.D., and Spitler, J.D. 2005. *Heating, ventilating, and air conditioning: analysis and design*. John Wiley & Sons, Inc. ISBN: 0-471-47015-5.

Mitchell, J.W. and Braun, J.E. 2013. *Principles of Heating, Ventilation, and Air Conditioning in Buildings*. John Wiley & Sons, Inc. ISBN: 978-0-470-62457-9.

Moss, K.J. 2007. *Heat and Mass Transfer in Buildings* (Second Edition). Taylor & Francis. ISBN: 978-0-415-40908-7.

Straube, J. and Burnett, E. 2005. *Building Science for Building Enclosures*. Building Science Press. ISBN: 0-9755127-4-9.

Course topics

- Importance of building science
- Elements of heat transfer in buildings
- Building energy balances
- Psychrometrics
- Thermal comfort
- HVAC systems and thermodynamics
- Mechanical, electrical, plumbing, and lighting systems
- Ventilation, infiltration, and indoor air quality
- Fluid flow in buildings
- Heating and cooling loads
- Building performance diagnostics
- Energy efficiency and green buildings

About you

- Who are you?
  - First and last name
  - Where are you from?
- What is your primary degree emphasis?
  - Undergraduate or graduate?
  - Engineering or other?
  - If graduate, masters or PhD?
    - Doing research (MS/PhD or MAS)?
- Why are you taking this course?
- Relevant work experiences

Potential research opportunities

The **Built Environment Research Group** at IIT is dedicated to investigating problems and solutions related to energy supply, consumption, and conservation, natural resource use, indoor and outdoor air pollution, environmental health, and sustainability within the built environment

Read more online: http://built-envi.com

Built
Environment
Research
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Advancing energy, environmental, and sustainability research within the built environment

IIT Armour College of Engineering
ILLINOIS INSTITUTE OF TECHNOLOGY

Course expectations

- Grading
  - Course is mixed undergraduate/graduate
  - Graduate students have higher expectations and will complete a few additional, more in-depth assignments
- Homework
  - Several HW assignments will be assigned throughout the semester
  - Will typically have 1 week to complete, due at beginning of next class
- Exams
  - One mid-term in October
  - Final exam in December
- Projects (graduate students only)
  - Final research project (w/ literature review) and presentation
  - Bi-weekly blog posts (every 2 weeks)
    - Undergraduate students can also blog for extra participation credit

Course grading

	CAE 331	CAE 513
• HW	350 (30%)	350 (25.5%)
• Mid-term	300 (30%)	300 (21.9%)
• Final exam	300 (30%)	300 (21.9%)
• Final project	n/a (0%)	250 (18.2%)
• Participation/blog	50 (5%)	170 (12.4%)
• Total	1000 (100%)	1370 (100%)

Grading scale for both 331 and 513:

A	B	C	D	F
90% and up	80.0-89.9%	70.0-79.9%	60.0-69.9%	<60.0%

Course website

- I will post lectures and updated syllabus on my website:
  - http://built-envi.com/courses/cae-331513-building-science-fall-2013/

- I will also post HWs, exams, lecture notes, syllabus, and other materials to Blackboard

- Our course blog is available at:
  - http://iitbuildingscience.wordpress.com/
  - Graduate students required to post every 2 weeks
    - 1st post is due 1 week from today

Tentative course schedule (continuously updated)

Week	Date	Lecture Topics	Reading	Assignment Due
1	Aug 19	Introduction to building science	Kreider Ch. 1	
2	Aug 26	Elements of heat transfer in buildings 1. Conduction, convection, radiation	Kreider Ch. 2	HW1 Blog post #1 (G)
3	Sep 2	*No class – Labor Day holiday*		HW2 (Tues. 9/3)
4	Sep 9	Elements of heat transfer in buildings 2. Solar radiation 3. Enclosure elements 4. Building energy balances	Kreider Ch. 2/6	Blog post #2 (G)
5	Sep 16	Psychrometrics and thermal comfort	Kreider Ch. 3-4	HW3
6	Sep 23	Overview of HVAC systems and thermodynamics	Kreider Ch. 9-10	Blog post #3 (G)
7	Sep 30	Mechanical, electrical, plumbing, and lighting *1. Away at conference (AAAR)*		HW4
8	Oct 7	*No class – Fall break day*		Blog post #4 (G)
9	Oct 14	Ventilation and indoor air quality *2. Away at conference (ASHRAE IAQ)*	Kreider Ch. 4	Mid-term exam
10	Oct 21	Fluid flow in buildings; air infiltration	Kreider Ch. 5	Blog post #5 (G)
11	Oct 28	Heating and cooling loads	Kreider Ch. 7-8	
12	Nov 4	Heating and cooling loads	Kreider Ch. 7-8	HW5 Blog post #6 (G)
13	Nov 11	Building performance diagnostics		HW6
14	Nov 18	Energy efficiency in buildings		Blog post #7 (G)
15	Nov 25	Final project presentations (graduate students)		
Final	Dec 2	Final exam		Final exam

Office hours

- My office hours are generally going to be 11:00-12:00 on Mondays and Wednesdays

- But I prefer that you make appointments with me via email
  - brent@iit.edu

Your TA this fall

- Elizabeth “Liz” Hausheer
  - ehaushee@hawk.iit.edu
- By appointment on Mondays and Wednesdays
  - Between 11 am to 1 pm on both days
  - Between 3 pm and 5 pm on Wednesdays
  - Email her to make an appointment
- Alumni Hall Room 217

Why a mixed UG/G course?

For undergraduate students:

- We are trying to help you adapt your basic physics and engineering knowledge to buildings
  - And to build a solid foundation for more advanced courses in architectural engineering

For graduate students (wide range of backgrounds):

- We are also trying to help you advance your physics and engineering knowledge to apply to buildings
  - And to build a foundation for advanced study, professional practice, and/or research in architectural engineering
  - Primarily reserved for graduate students without significant building science or architectural engineering background

Questions thus far?

Today's topics

- Introduction to building science
- Review of fundamentals from prerequisite courses
  - Including units and definitions
- Assign HW #1

INTRODUCTION TO BUILDING SCIENCE

What is building science?

Building science is the application of physics to the built environment

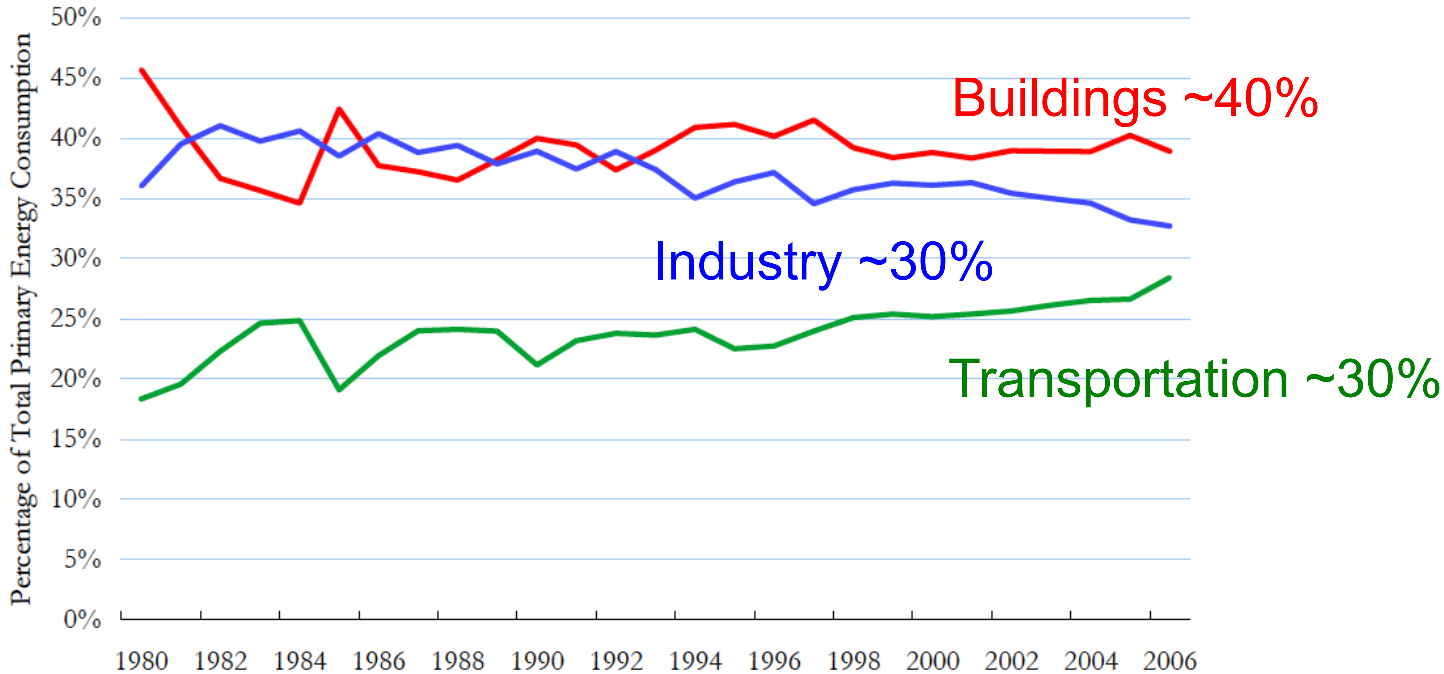
- Building science involves studying all of the physical phenomena that govern energy use, human comfort, function, and overall performance of buildings

- Building science requires complete understanding of:
  - Weather conditions, subterranean (soil) conditions, building material characteristics, physics, chemistry, biology, and human physiology
  - Each of these combines to influence energy consumption, environmental impacts, environmental control, system design, maintenance, construction, building longevity, human comfort and health, and overall sustainability

Why study building science?

- How many of you are in a building right now?
  - Birds build nests
  - Rabbits dig holes
  - People build buildings
- How much time do you think people spend indoors, on average?
- How much energy do buildings use in the U.S.?
- How much money do we spend on energy use in buildings in the U.S.?

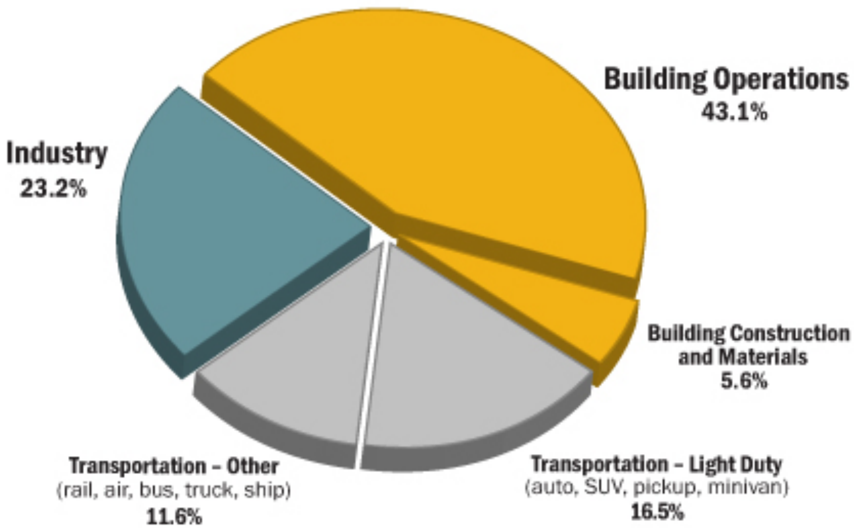
Buildings use *a lot* of energy



Buildings use ~40% of energy in the U.S.

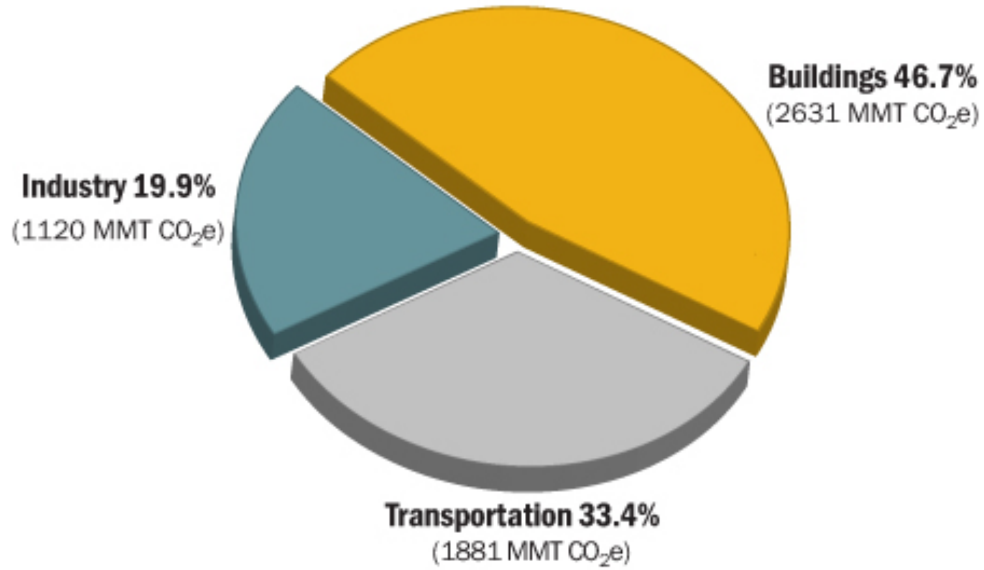
Buildings in the U.S. account for ~7% of the total amount of energy used in the world

Buildings account for *a lot* of emissions and resource use



U.S. Energy Consumption by Sector

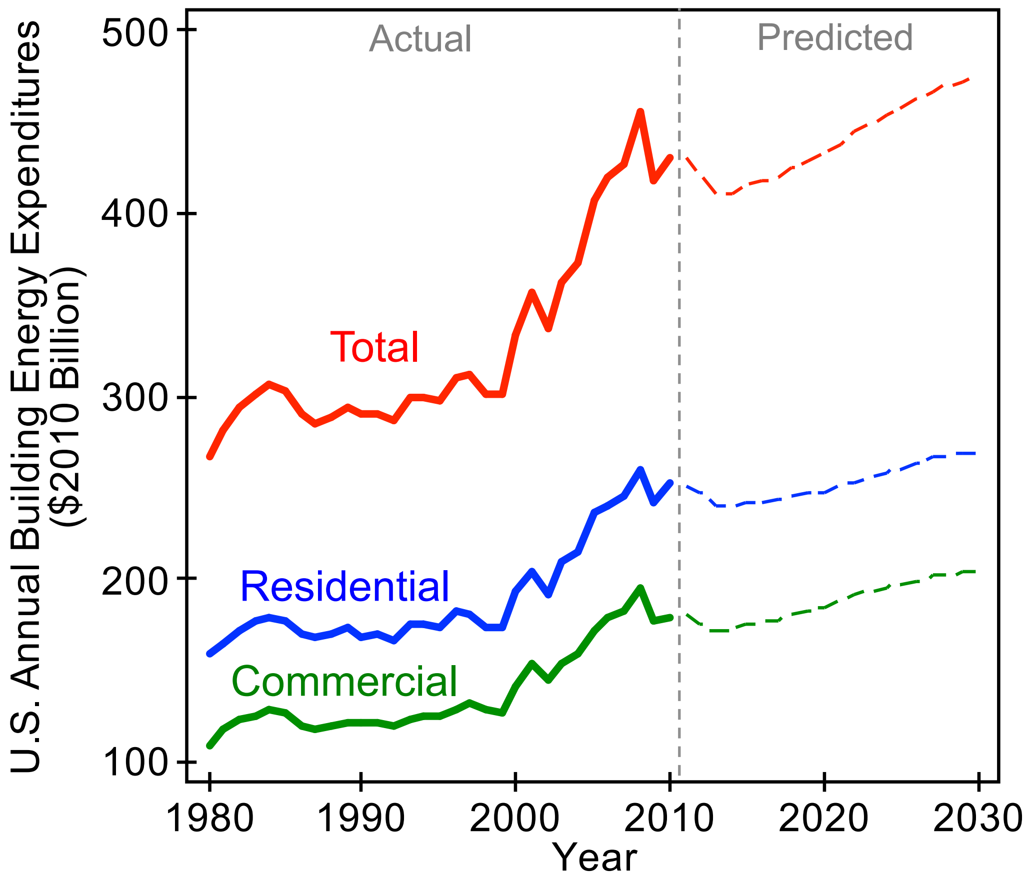
Source: ©2011 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2011).



U.S. CO_2 Emissions by Sector

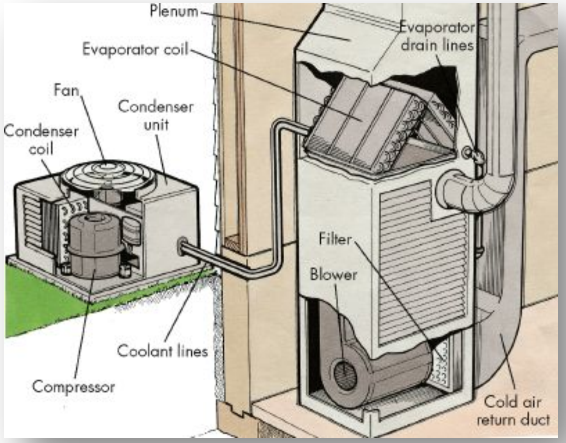
Source: ©2011 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2011).

Building energy use costs *a lot* of money



U.S. building energy expenditures totaled ~$430 billion in 2010

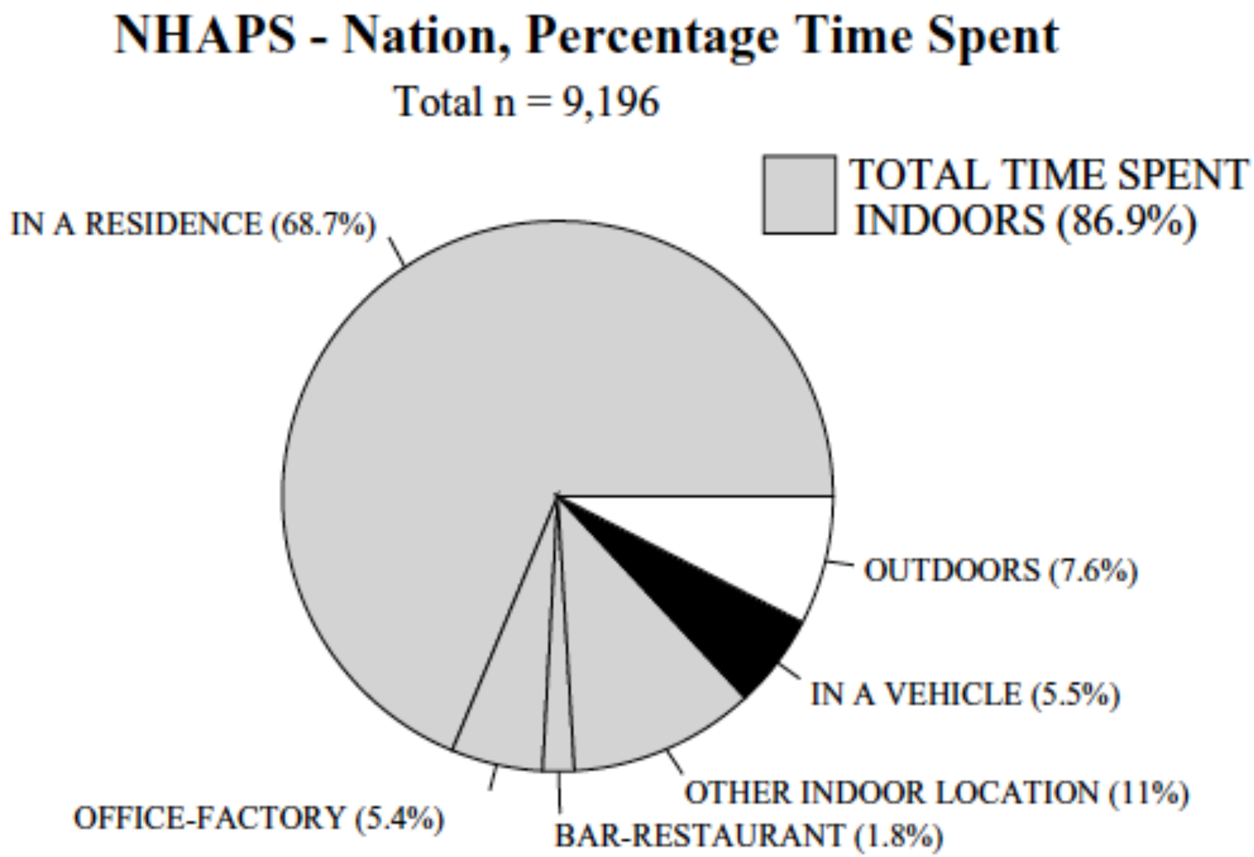
Approximately 3% of our GDP



Approximately 1/3 of building energy use is for space conditioning

~1% of our GDP is spent on heating and cooling buildings

We spend *a lot* of time in buildings



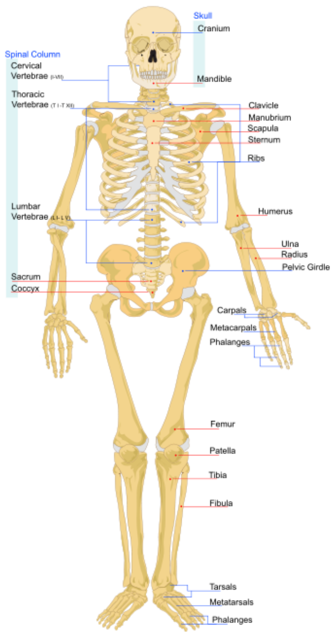
- Americans spend almost 90% of their time indoors
  - 75% at home or in an office

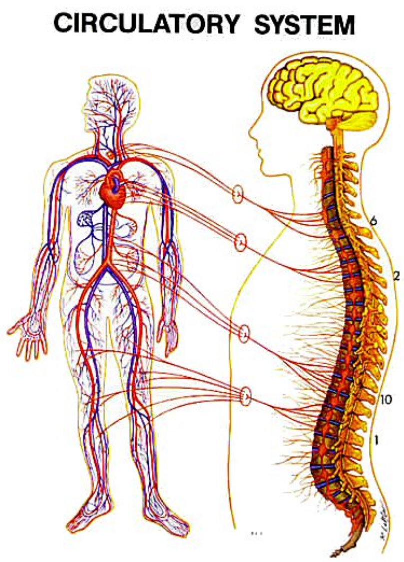
Klepeis et al., *J Exp. Anal. Environ. Epidem.* **2001**, 11, 231-252

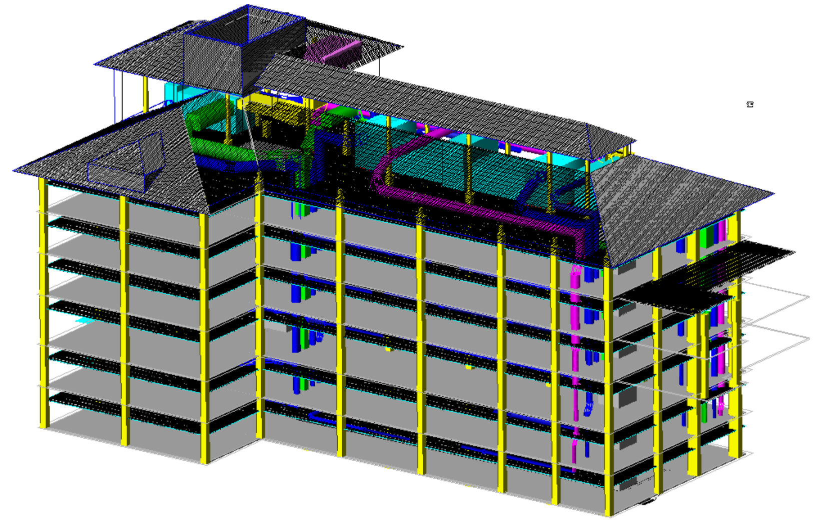
Buildings impact people, energy, and the environment

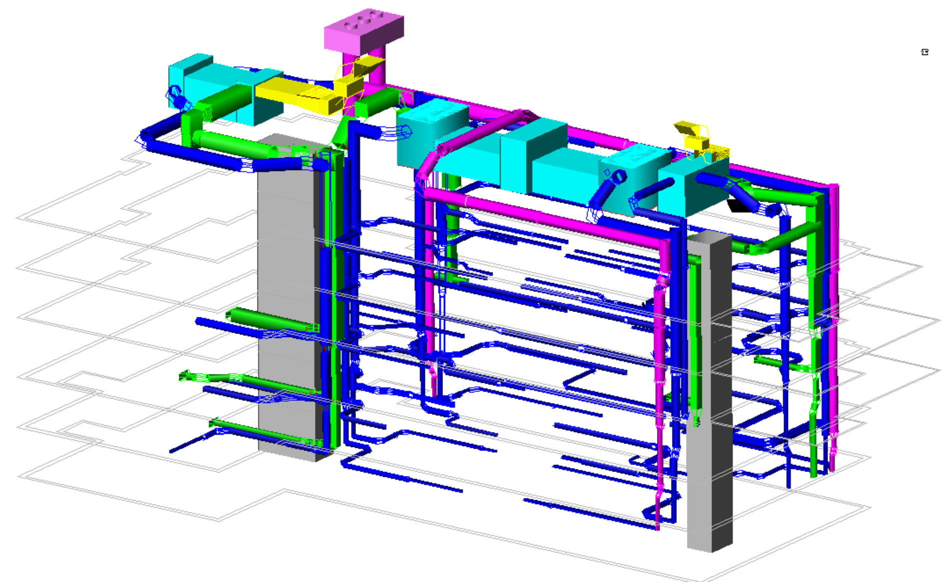
The design, construction, and operation of buildings, including their heating, ventilation, and air-conditioning (HVAC) systems and building envelopes, greatly affect their contribution to energy use, greenhouse gas emissions, financial expenditures, and human exposures to airborne pollutants in the indoor environment

Building science in context









Courtesy Atila Novoselac, UT-Austin

Building science in context

- Structural
- Mechanical
- Construction
- Electrical
- Plumbing
- Architectural

All of these disciplines must all work together to design, build, and operate a building successfully and efficiently

- Architectural engineering has become a catch-all for many of these disciplines

Building science and other detailed courses in ARCE

- Enclosure/architectural
  - CAE 463/524 Building Enclosure Design
- Mechanical
  - CAE 464 HVAC Design
  - CAE 465/526 Energy Conservation Design in Buildings
  - ENVE 576 Indoor Air Pollution (partial coverage)
- Electrical
  - CAE 334/502 Acoustics and Lighting
  - CAE 466/528 Building Electrical Systems Design
  - CAE 467/521 Lighting Systems Design
- Plumbing and fire protection
  - CAE 424/510 Fire Dynamics
  - CAE 425/511 Fire Protection and Life Safety in Building Design
  - CAE 461 Plumbing and Fire Protection Design

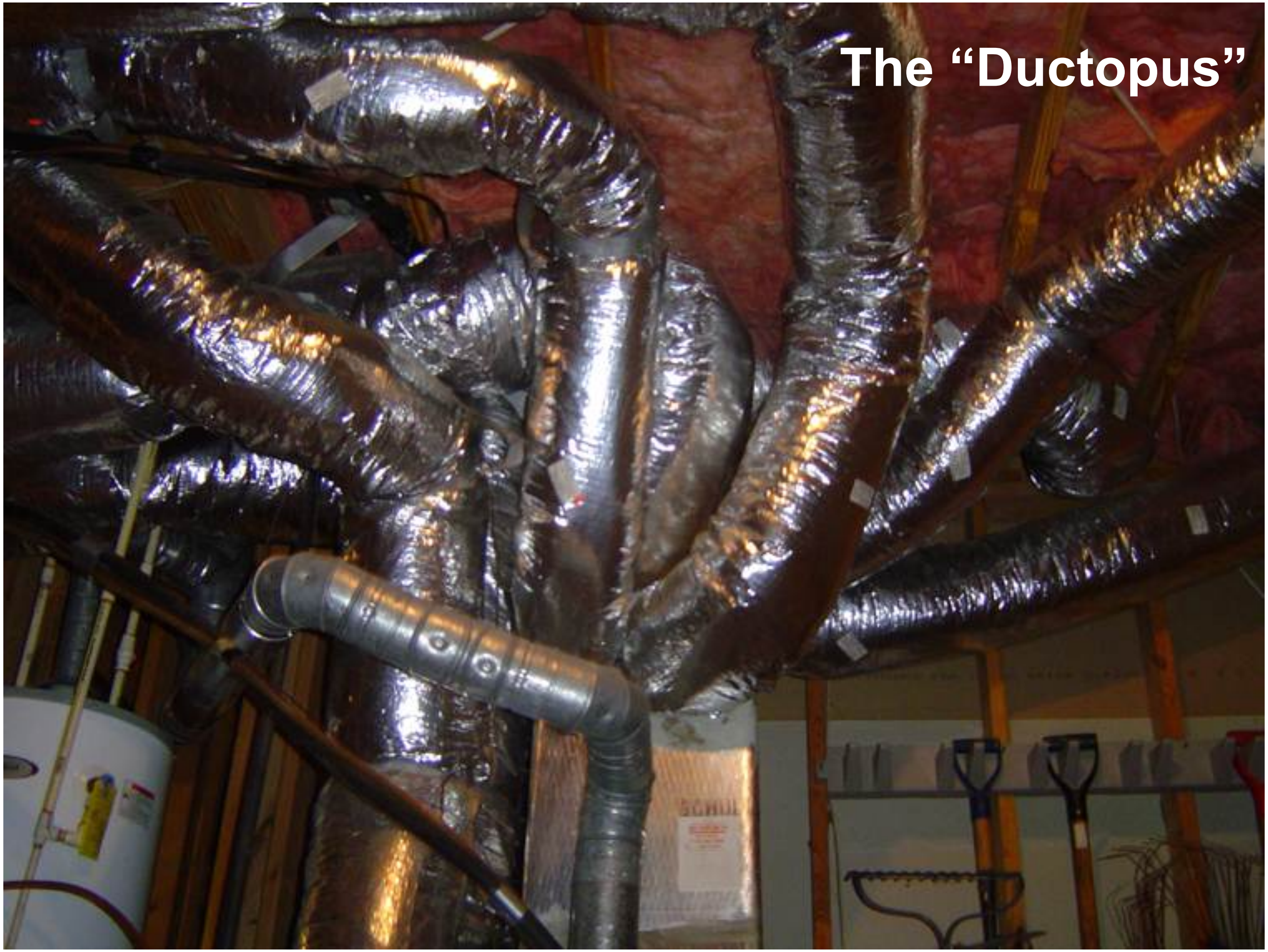
What happens when you don't understand building science?

http://www.energyvanguard.com/blog-building-science-HERS-BPI/bid/55801/Fail-Ignorance-of-Building-Science-Is-No-Excuse

What happens when you don't understand building science?

http://www.hvacfun.com/hall-shame-22.htm

What happens when you don't understand building science?



http://www.greenbuildingadvisor.com/blogs/dept/building-science/should-flex-duct-be-banned

What happens when you don’t understand building science?

http://www.greenbuildingadvisor.com/blogs/dept/building-science/should-flex-duct-be-banned

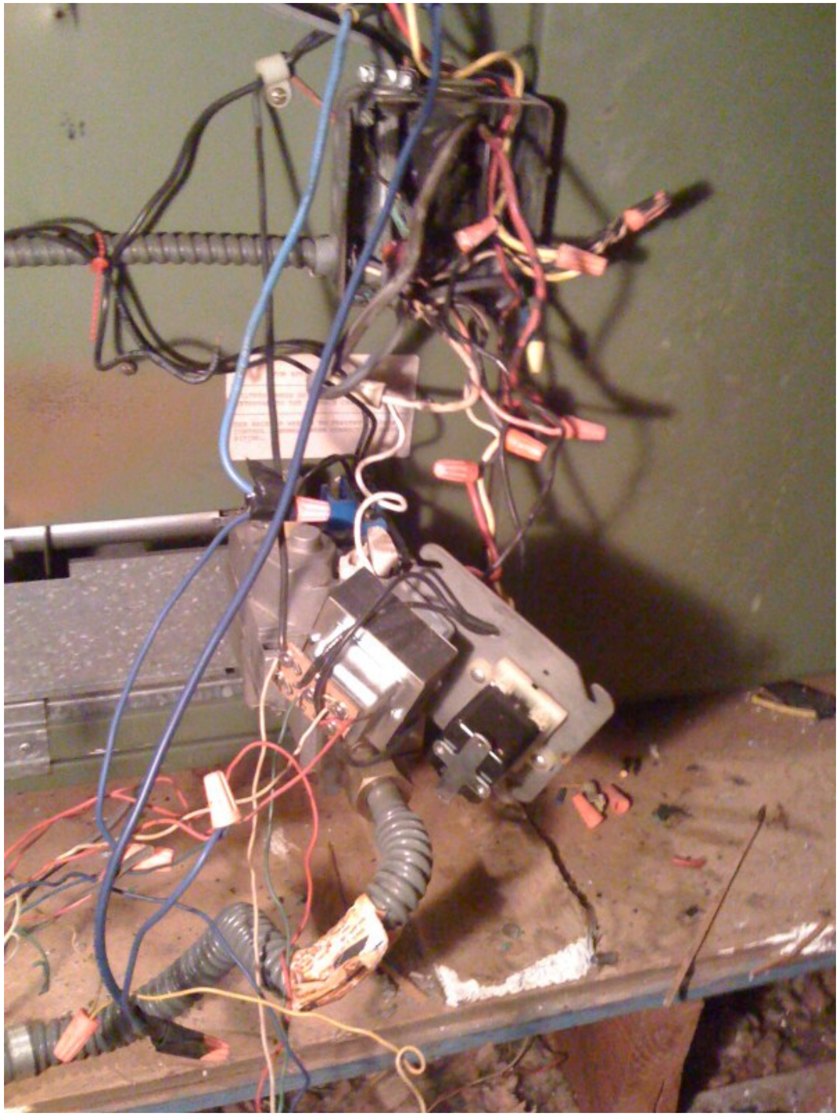
What happens when you don't understand building science?

http://www.hvacfun.com/hall-shame-24.htm

What happens when you don’t understand building science?

http://www.hvacfun.com/hall-shame-43.htm

What happens when you don't understand building science?



http://www.hvacfun.com/hall-shame-27.htm

http://www.hvacfun.com/hall-shame-35.htm

What happens when you don't understand building science?

http://www.hvacfun.com/hall-shame-59.htm

What happens when you don't understand building science?

http://www.hvacfun.com/hall-shame-82.htm

What happens when you don't understand building science?

C

Excessive length of duct installed causing sharp bends.

Fan housing was oriented in the correct direction to allow proper exhaust duct installation.

BUILDING SCIENCE RESOURCES

Important organizations to know

- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
  - Handbook of Fundamentals
  - Standards and design guidelines
- Lawrence Berkeley National Laboratory (LBNL)
- Oak Ridge National Laboratory (ORNL)
- Building Science Corporation
- RESNET
- EPA Energy Star
- National Institute of Building Sciences
- National Resources Canada
- ASTM
- Passive House Institute (US)
- Pacific Northwest National Lab (PNNL)
- American Council for an Energy Efficient Economy (ACEEE)

ASHRAE

RESNET
RESIDENTIAL ENERGY SERVICES NETWORK

BERKELEY LAB

National Institute of BUILDING SCIENCES
An Authoritative Source of Innovative Solutions for the Built Environment

Oak Ridge National Laboratory
Buildings Technology Center

PHIUS
Passive House Institute US

ENERGY STAR

bsc Building Science Corporation

Important publications to know

- Publications*
  - *ASHRAE Journal*
  - *HVAC&R Research*
  - *ASHRAE Transactions*
  - *Building and Environment*
  - *Energy and Buildings*
  - *ASCE Journal of Architectural Engineering*

*I believe these are all available through the Galvin Library

- Online access: http://library.iit.edu/

ASHRAE Handbook of Fundamentals

ASHRAE

Fundamentals 2013

(SI Edition)

Commercial Resources

ASHRAE Bookstore

COMMENT HELP MAIN MENU

More . . .

REVIEW OF PREREQUISITES

Review of prerequisite topics

- CAE 208: Thermal-fluids engineering 1
  - Basic laws of thermodynamics
  - Energy and mass flows
  - Introduction to fluid mechanics

- CAE 209: Thermal-fluids engineering 2
  - Finish fluid mechanics
  - Heat and mass transfer analysis
  - Energy and momentum equations
  - Convection, conduction, and radiation

Building science units and dimensions

- Within architectural engineering, both SI and IP (inch-pound) units are used
  - I am sorry for that
- IP is dominant in US engineering
  - (But changing slowly)
- We will use both in this class
  - So it will be useful to memorize the most commonly used constants and conversion factors between both units

Building science units and dimensions

- Lengths are usually in feet [ft] or meters [m]
- Volumes are usually in cubic feet [ft^3] or cubic meters [m^3]
- Volumetric flow rates are usually in [ft^3/min] (CFM)
  - Sometimes [m^3/hr], [m^3/s], [L/s]
  - Water flows are often [L/min] (lpm) or [gal/min] (gpm)
- Temperatures are either Fahrenheit [°F] or Celsius [°C]
  - Sometimes Kelvin [K]
  - Rarely Rankine [R]
- Velocities are either [ft/s], [m/s], or sometimes [cm/s]
- Concentrations are parts per million [ppm], parts per billion [ppb], or micrograms per cubic meter [$\mu g/m^3$]
- Mass is typically [lb_m] or [kg]

More building science units

- Energy is usually in [J] or [Btu]
  - Or [kWh] (for electric) or [therms] (for natural gas)
    - 1 kWh = 3412 Btu
    - 1 therm = 10^5 Btu

- Power is usually [W = J/s] or [Btu/hr]
  - Tons of refrigeration [1 ton = 12000 Btu/hr = 3412 W]

- Pressure is usually [Pa] or [in-wg or in w.c.] (inches of water)
  - Larger pressures are also [in-Hg] (inches of mercury)
    - Or [psi] (pounds per square inch)

Some very important definitions

Energy

- Energy is the capacity of a system to do work
  - We use this term a lot
  - Units: Joules, Btu, or kWh
- Different forms of energy:
  - Thermal, radiative, solar, nuclear, geothermal, hydrocarbon
  - Energy efficiency
    - Energy that is not utilized
  - Embodied or embedded energy
    - The energy required to extract resources, manufacture, and transport a product
- Energy use depends on the rate of energy use and the time/ duration of operation
  - Rate of use = power

Power

- Power is the rate at which energy is produced or consumed
  - Units are energy per time
  - Btu per hour (Btu/hr)
  - Watt (J/s) or kilowatt (kW)

- Be careful when using units associated with energy and power
  - People often confuse these

- Example: Batteries don’t store power; they store energy
  - They release that energy (Watt-hours) at a rate determined by the equipment’s power draw (Watts, or amperage)

Importance of units

- Units are EVERYTHING in architectural engineering
- Your first HW (assigned today) will cover unit conversions
- If you can understand and convert units, and if you can get a sense of scale and magnitude associated with units, you will be well on your way to becoming a building scientist

Unit conversion examples

Unit conversion example problem:

- Water of density ρ = 1000 kg/m^3 (62.44 lbm/ft^3) flows at a rate of V = 10 gal/min (0.6308×10^{-3} m^3/s) through a pipe of interior diameter D = 1.0 inches (2.54 cm)

- Find the velocity pressure, given by the formula:

$$P = \frac{\rho v^2}{2}$$

- Provide answer in units of [Pa] and [in-WG]

Unit conversion examples

Order of magnitude example problem:

- From what height do you have to jump into a bathtub to warm up the water by 1 degree C (1.8 degree F), assuming that all of the kinetic energy from the jump goes into heating the water (no losses)?

HOW BUILDING SCIENCE AFFECTS ENERGY, ECONOMICS, AND THE ENVIRONMENT

Building energy use

- How do we utilize energy in buildings?

- We burn some fuels directly
  - Natural gas, oil

- We burn other fuels to generate electricity
  - Electric conversion efficiency is not 100%
  - There are also distribution and transmission losses

- Great resource: The Building Energy Data Book
  - http://buildingsdatabook.eren.doe.gov/

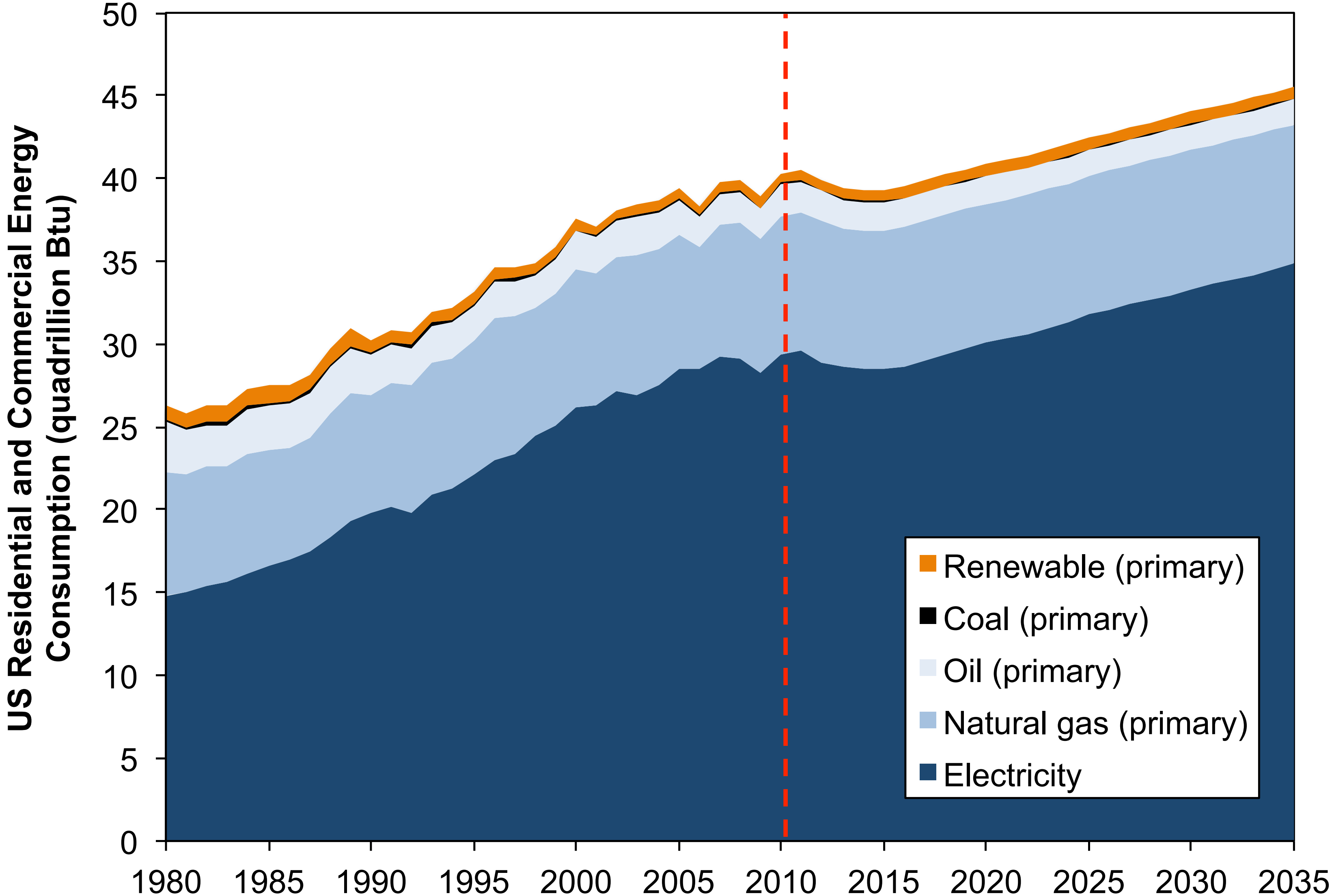
How much energy does the US use?

- http://www.theatlantic.com/video/archive/2013/08/how-much-energy-does-the-us-use/278324/

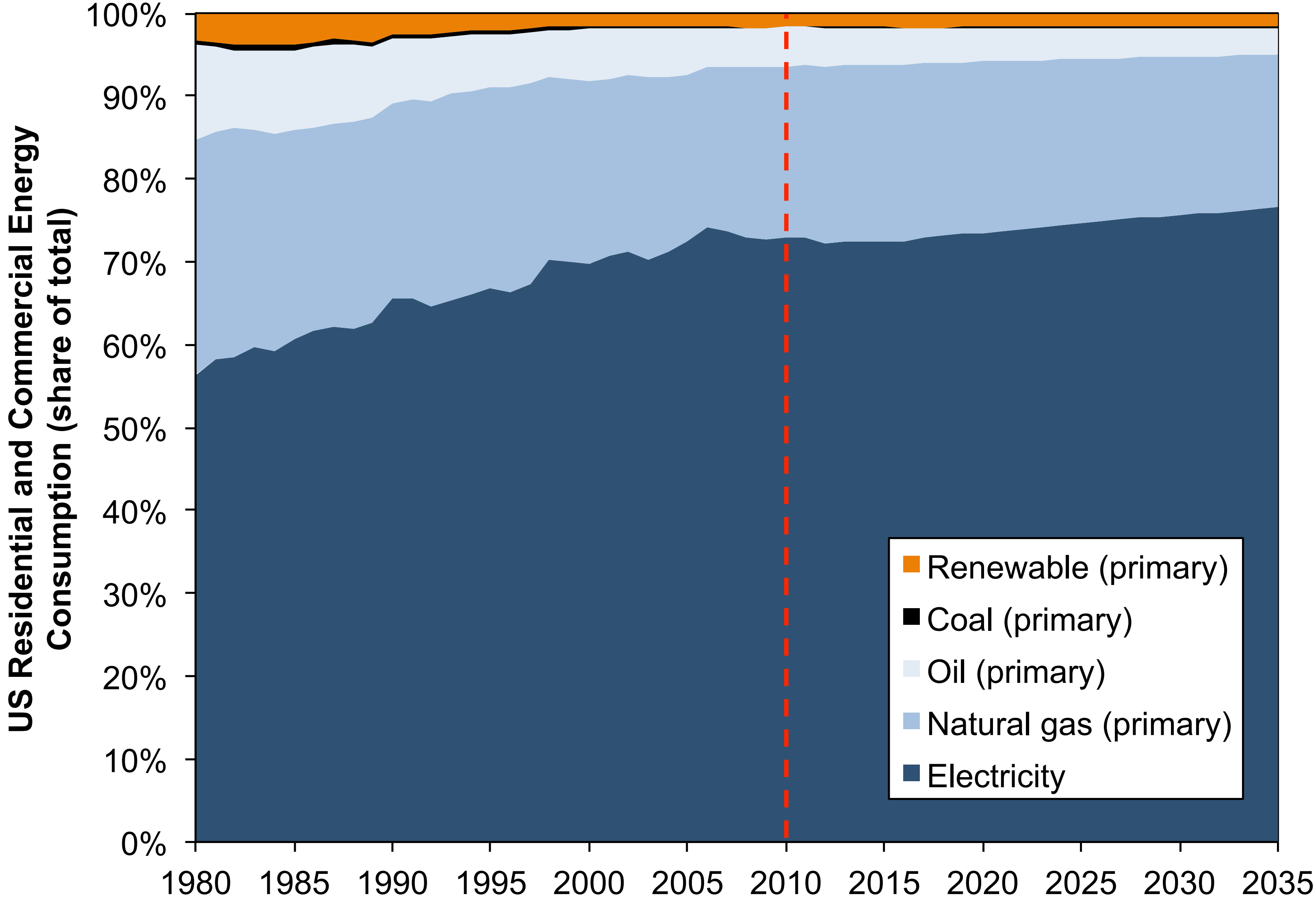
How do we use energy at home?

- http://www.theatlantic.com/video/archive/2013/08/how-do-we-use-energy-at-home/278439/

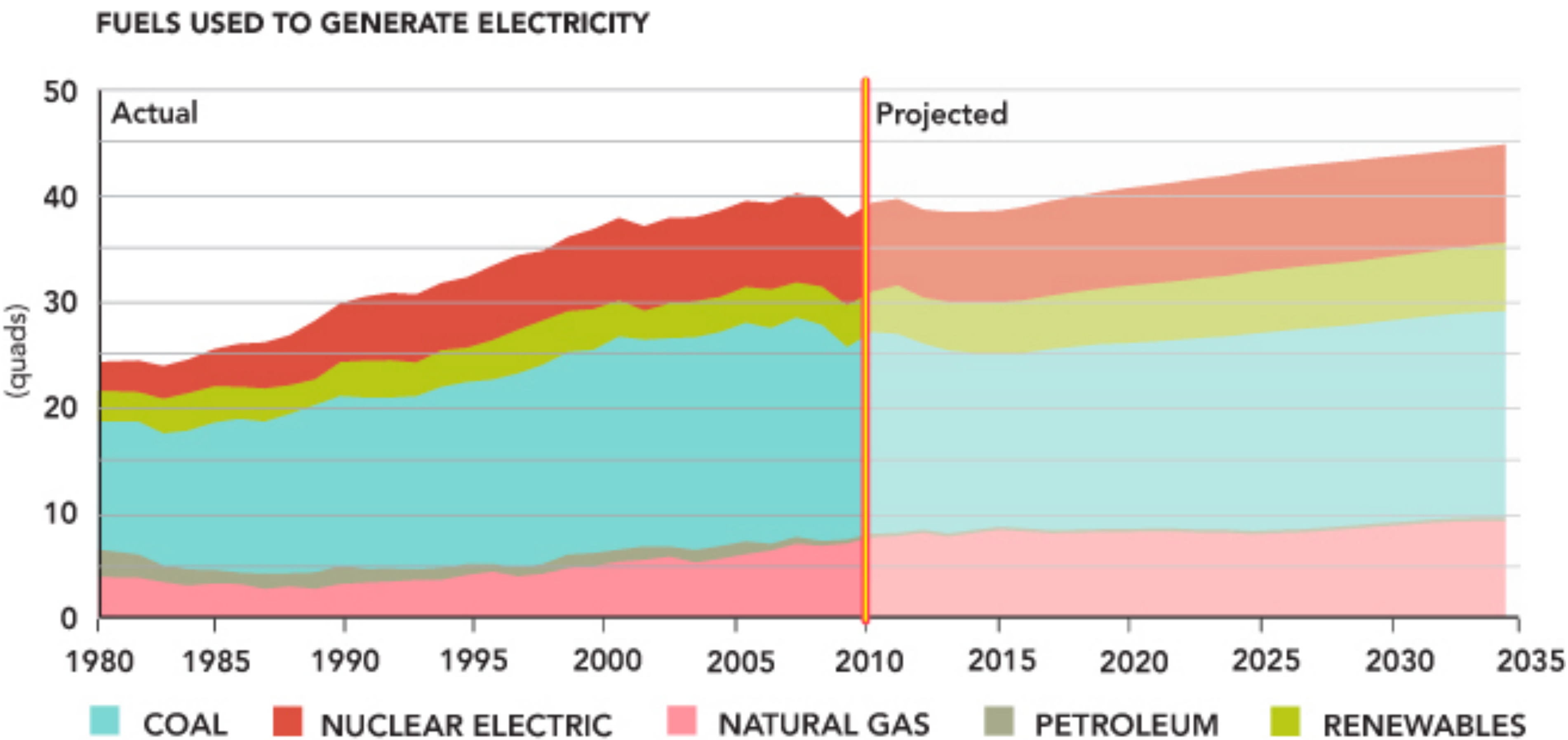
US building energy consumption over time (by fuel)



Fraction of US building energy consumption over time (by fuel)

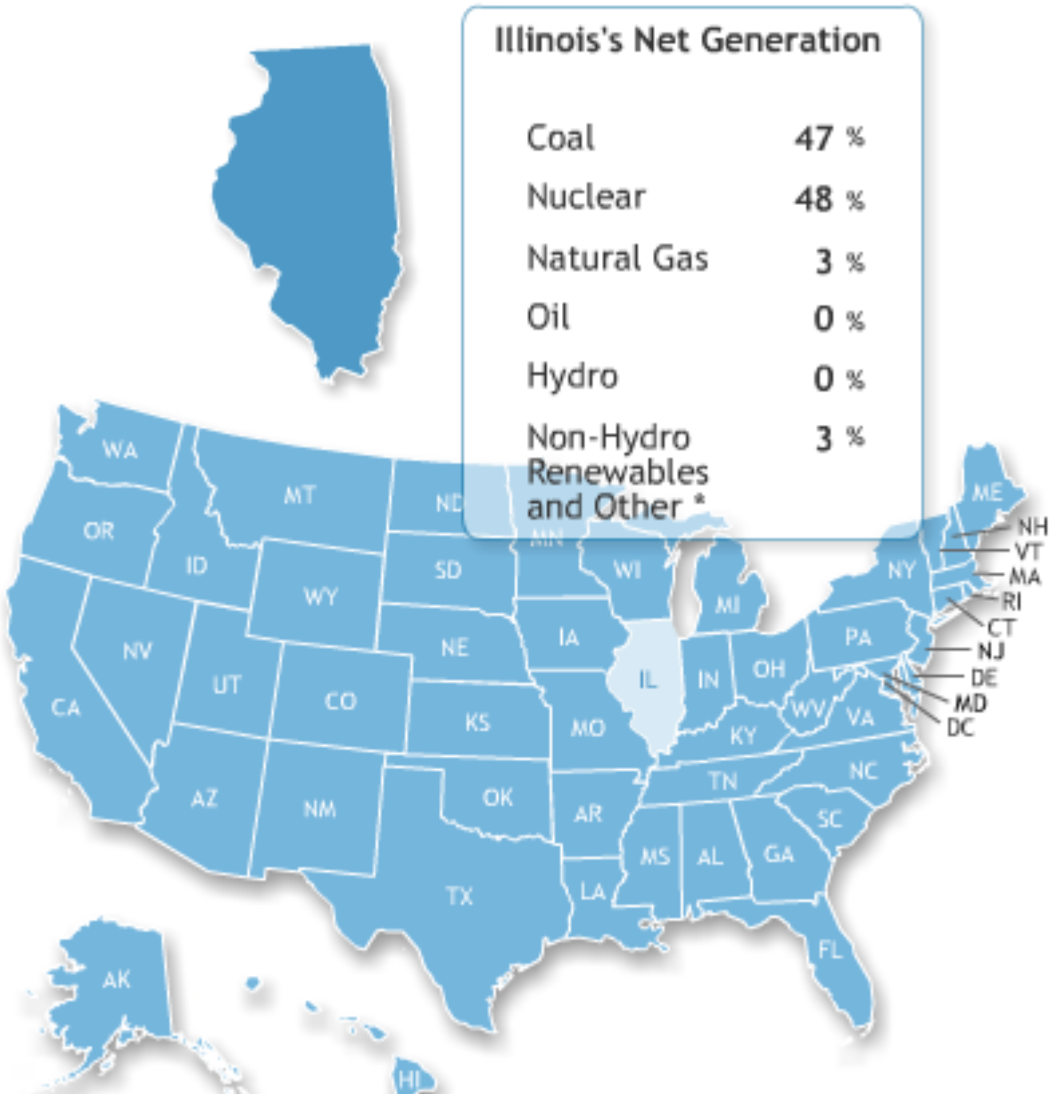


Where do we get our electricity?



http://buildingsdatabook.eren.doe.gov/ChapterIntro6.aspx?6

How does Illinois get its electricity?



http://www.getenergyactive.org/fuel/state.htm

Conversion efficiency for electric generators

	Coal	Petroleum	Nat. Gas	Nuclear
Steam generator	34%	33%	33%	33%
Gas turbine	-	25%	29%	-
Internal combustion	-	33%	34%	-
Combined cycle	-	32%	45%	-

- Natural gas used directly in buildings is typically 80-90% efficient or higher

http://www.eia.gov/tools/faqs/faq.cfm?id=107&t=3

Greenhouse gas emissions based on building fuel

1.4.8 2010 Carbon Dioxide Emission Coefficients for Buildings (MMT CO2 per Quadrillion Btu)

	All Buildings	Residential Buildings	Commercial Buildings
Coal�			
Average (2)	95.35	95.35	95.35
Natural Gas			
Average (2)	53.06	53.06	53.06
Petroleum Products			
Distillate Fuel Oil/Diesel	73.15	-	-
Kerosene	72.31	-	-
Motor Gasoline	70.88	-	-
Liquefied Petroleum Gas	62.97	-	-
Residual Fuel Oil	78.80	-	-
Average (2)	69.62	68.45	71.62
Electricity Consumption (3)			
Average - Primary (4)	57.43	57.43	57.43
Average - Site (5)	178.3	179.1	177.9
New Generation			
Gas Combined Cycle - Site (6)	112.5	112.5	112.5
Gas Combustion Turbine - Site (6)	171.4	171.4	171.4
Stock Gas Generator - Site (7)	133.9	133.9	133.9
All Fuels (3)			
Average - Primary	56.23	55.79	56.77
Average - Site	111.4	105.6	118.7

http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=1.4.8

Greenhouse gas emissions based on building end-use

1.4.2 2010 Buildings Energy End-Use Carbon Dioxide Emissions Splits, by Fuel Type (Million Metric Tons) (1)

	Natural	Petroleum								
	Gas	Distil.	Resid.	LPG	Oth(2)	Total	Coal	Electricity (3)	Total	Percent
Space Heating (4)	272.9	49.0	6.7	18.7	2.6	77.0	6.2	128.2	484.3	21.3%
Space Cooling	2.3							340.5	342.8	15.1%
Lighting								334.1	334.1	14.7%
Water Heating	91.9	9.2		4.6		13.7		98.5	204.1	9.0%
Refrigeration (5)								149.8	149.8	6.6%
Electronics (6)								143.0	143.0	6.3%
Ventilation (7)								95.2	95.2	4.2%
Computers								68.2	68.2	3.0%
Wet Cleaning (8)	2.9							57.8	60.8	2.7%
Cooking	20.9			1.9		1.9		36.5	59.4	2.6%
Other (9)	15.8	0.9		19.1	3.8	23.9		158.4	198.1	8.7%
Adjust to SEDS (10)	36.2	18.4				18.4		75.4	129.9	5.7%
Total	**442.9**	**77.5**	**6.7**	**44.3**	**6.4**	**134.8**	**6.2**	**1685.7**	**2269.6**	100%

http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=1.4.2

Other pollutant emissions from buildings

1.4.10 2010 Emissions Summary Table for U.S. Buildings Energy Consumption (Thousand Short Tons) (1)

	Wood/SiteFossil	Buildings Electricity	Total	U.S. Total	Buildings Percent of U.S. Total
SO2	433	3,814 (2)	4,247	7,938	54%
NOx	656	1,554	2,210	12,914	17%
CO	2,926	540	3,466	67,790	5%
VOCs	219	34	253	13,443	2%
PM-2.5	378	294	672	4,495	15%
PM-10	383	318	701	10,778	7%

Note(s): 1) VOCs = volatile organic compounds; PM-10 = particulate matter less than 10 micrometers in aerodynamic diameter. PM-2.5 = particulate matter less than 2.5 micrometers in aerodynamic diameter. CO and VOCs site fossil emissions mostly from wood burning. 2) Emissions of SO2 are 28% lower for 2002 than 1994 estimates since Phase II of the 1990 Clean Air Act Amendments began in 2000. Buildings Energy Consumption related to SO2 emissions dropped 27% from 1994 to 2002.

Designing for efficiency: who pays for it?

- First costs
  - Equipment size, capacity, and efficiency
  - Building and system design parameters

- Operating costs
  - Built-in equipment
  - Operational characteristics
  - Human beings!

- Energy and economic analysis early in the design stage can optimize balances between first costs and operating costs

Payback periods

- Making a design choice is easy when Option A has a lower first cost (purchase + installation) AND costs less to operate than Option B
  - But the decision is usually more complicated

- Suppose model A costs $600 and draws electricity at an average rate of 150 W
- Model B costs $700 and draws only 100 W
- If the cost of electricity is 10 cents per kWh and we assume these two pieces of equipment operation 24/7 (8760 hrs/yr):
  - What are the annual savings due to Model B?
  - Is it worth the additional cost for Model B?

Payback periods

- Payback period = ($ investment) / ($ annual savings)

General rules of thumb:

- If a payback period is less than 1/3 of the estimated lifetime of the investment, it is a ***very profitable*** investment

- If a payback period is less than ½ of the estimated lifetime of the investment, it is considered a ***profitable*** investment

MOVING FORWARD

HW #1 due next week

All students:

- HW problems from Chapter 1
- Available on blackboard; Due Monday 8/26 before class

Graduate students:

- Graduate students need to post their first blog post by next Monday
  - Demonstration: http://iitbuildingscience.wordpress.com

- All students will be invited to join the blog as authors via email

Tips on blog posts

- Great examples of building science blogs:

- Energy Vanguard
  - http://www.energyvanguard.com/blog-building-science-HERS-BPI/

- Green Building Advisor
  - http://www.greenbuildingadvisor.com/blogs
  - Specifically:
    - Martin Holladay's Musings of an Energy Nerd
      - http://www.greenbuildingadvisor.com/blogs/dept/musings
    - Allison Bailes' Building Science Blog
      - http://www.greenbuildingadvisor.com/blogs/dept/building-science

Tips on blog posts

- Don’t be too short
  - No need to be too long
  - Approximately 300 to 500 words is a good target
- Ideas for topics/categories
  - New technologies
  - Example projects/designs
  - Helpful videos
  - How-to demonstrations
  - Measurements in your own home (request equipment from me)
  - Unsubstantiated claims department

Next time

- Heat transfer in buildings