The Florida Advanced Technological Education (FLATE) Center wishes to make available, for educational and non-commercial purposes only, materials relevant to the "EST1830 Introduction to Alternative/Renewable Energy" course comprised of images, texts, facilitator's notes, and other demonstration materials.

This instructional resource forms part of FLATE's outreach efforts to facilitate a connection between students and teachers throughout the State of Florida. We trust that these activities and materials will add value to your teaching and/or presentations.

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Introduction to Alternative and Renewable Energy

EST1830

4. Energy Efficiency

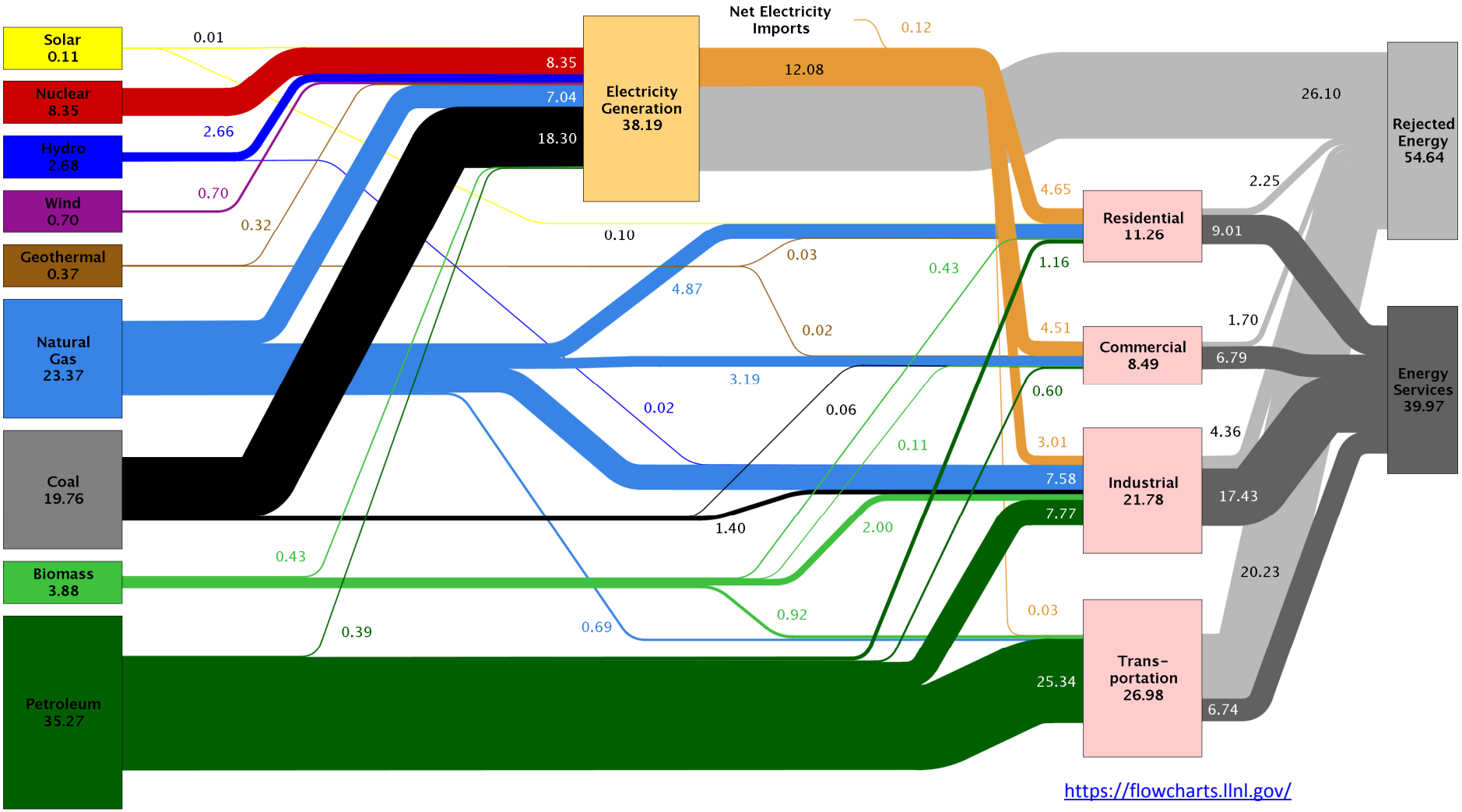
Why Energy Efficiency?

Building

Technologies

Why Energy Efficiency?

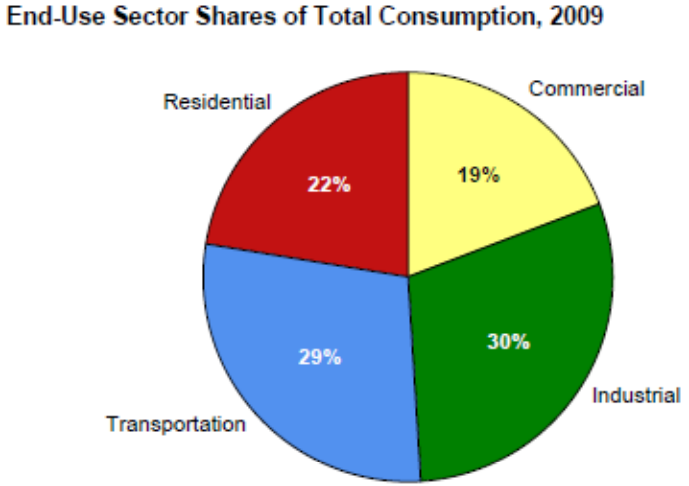
Lawrence Livermore National Laboratory

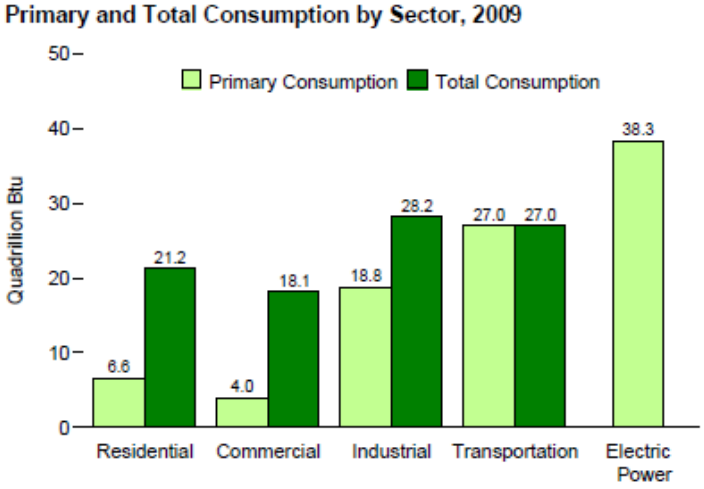


https://flowcharts.llnl.gov/

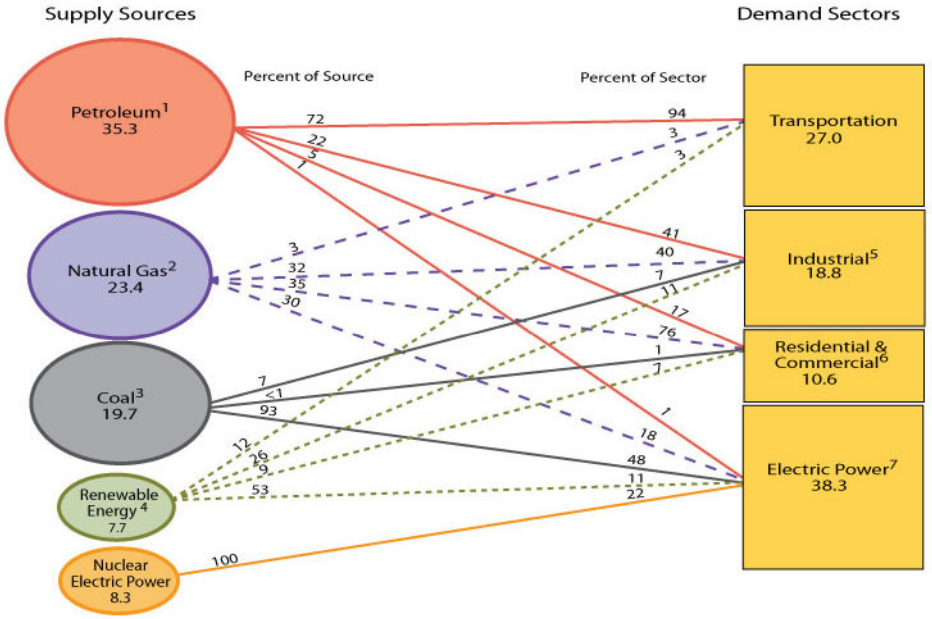
Source: LLNL 2010. Data is based on DOE/EIA-0384(2009), August 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Energy Consumption by Sector





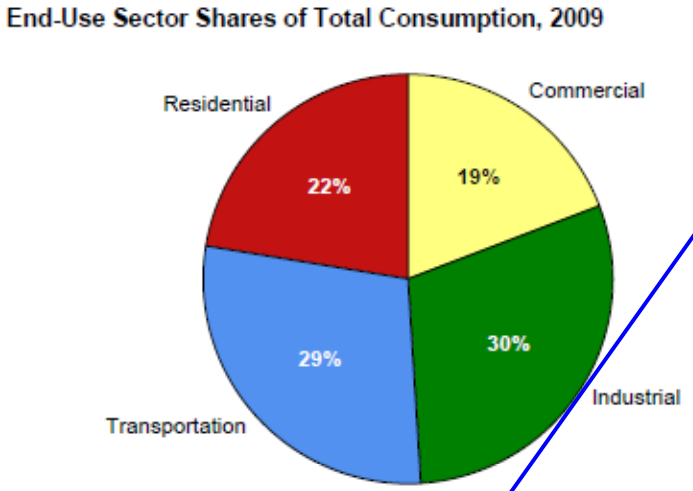
Total Consumption= Primary consumption + electrical retail sales + electrical system losses.



U.S. Energy Information Administration / Annual Energy Review 2009

Primary Energy consumption by source, 2009

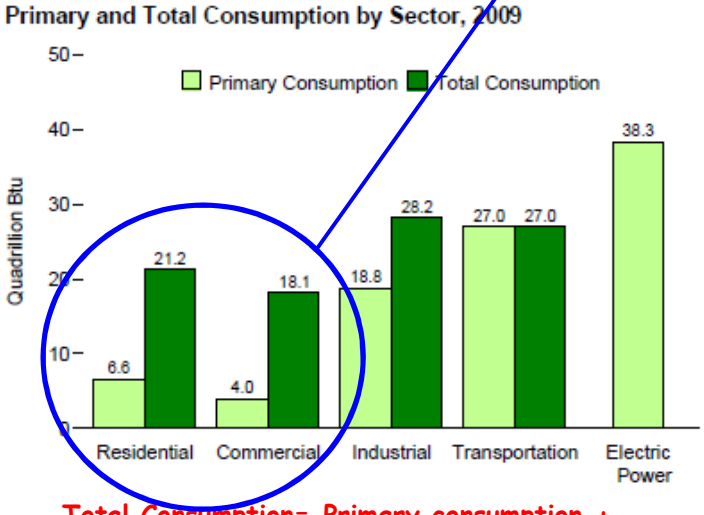
Energy Consumption by Sector



Total buildings (Residential + Commercial): 41% !!

	Total Consumption (Quad BTU)	Primary consumption (Quad BTU)	Electrical Sales (Quad BTU)	Electrical System Losses (Quad BTU)
Residential	21.21	6.61	4.65	9.95
Commercial	18.14	3.97	4.51	9.66
Compare with Industrial Sector				
Industrial	28.2	18.75	3.01	6.44

U.S. Energy Information Administration / Annual Energy Review 2009



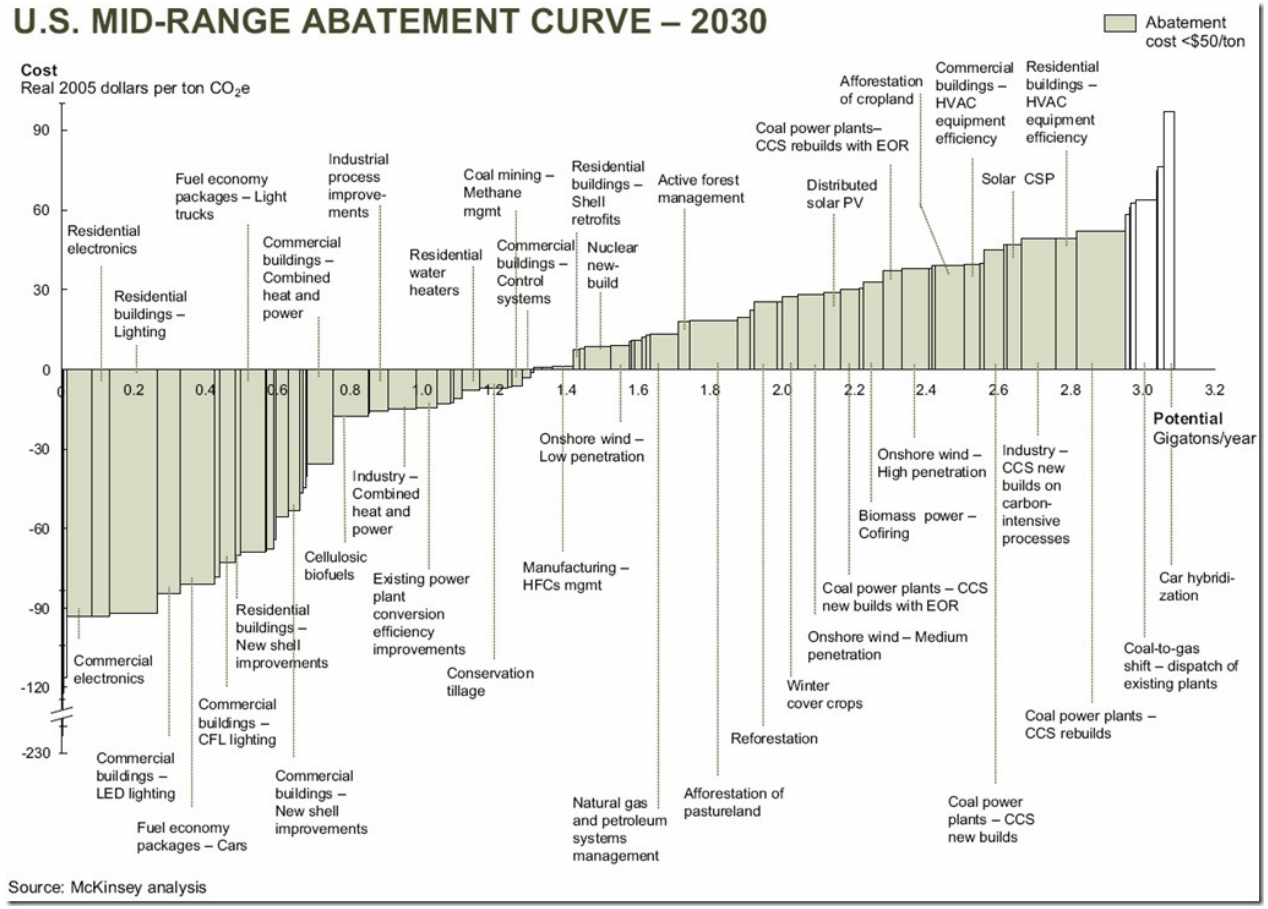
Total Consumption= Primary consumption + electrical retail sales + electrical system losses.

	Losses as % of total consumption
Residential	47%
Commercial	53%
Compare with Industrial Sector	
Industrial	23%

Electrical System Energy Losses: The amount of energy lost during generation, transmission, and distribution of electricity, including plant and **unaccounted-for uses**.

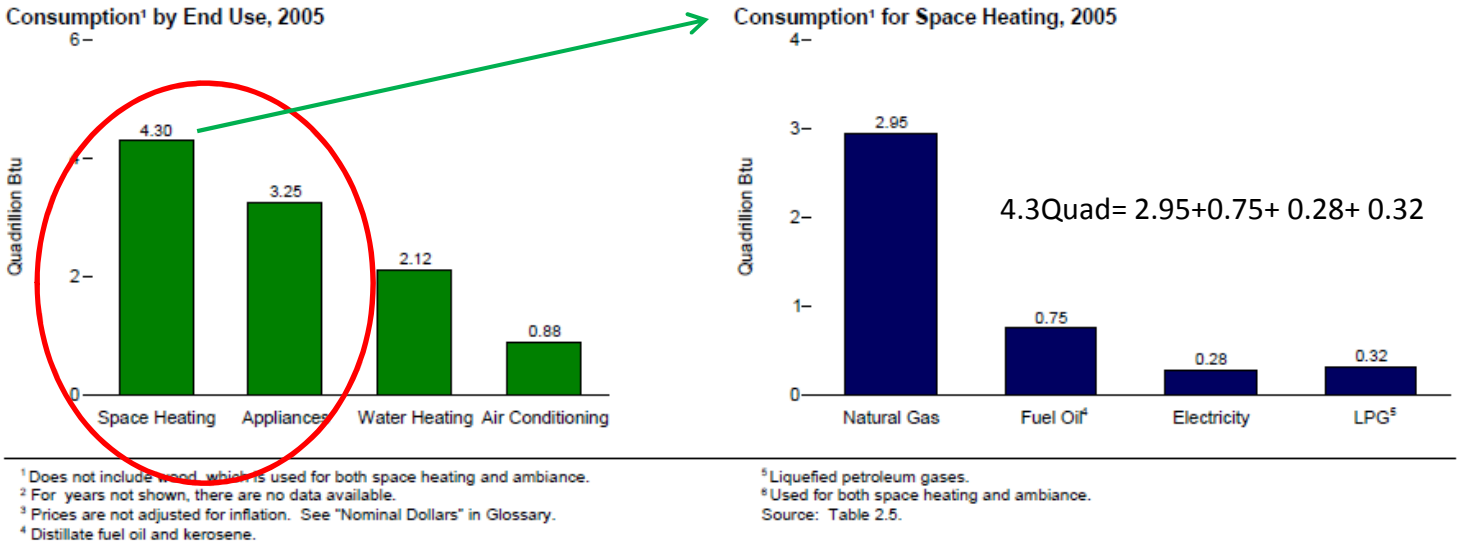
Buildings Matter

- 30-50% of US energy use: 41% in 2009
- Large cost-effective potential for reductions from efficiency in new AND existing buildings
- Many of the most cost-effective measures are in Buildings



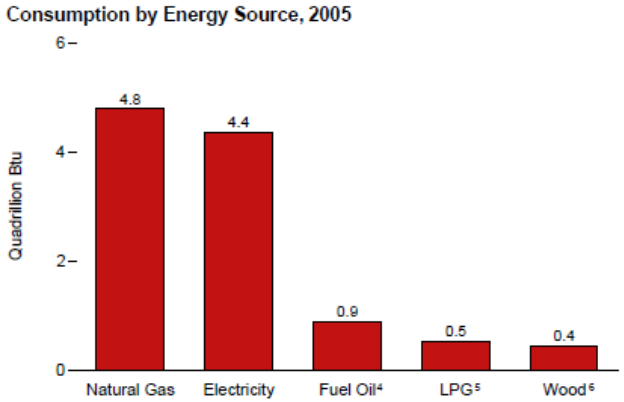
The vertical axis shows the potential total cost of a given technology. Technologies below the line are ones that save money. Technologies above the line cost money. The horizontal axis shows the potential total amount of carbon (CO2) saved in gigatons.

Residential High Hitters



[1] Does not include wood, which is used for both space heating and ambiance.
[2] For years not shown, there are no data available.
[3] Prices are not adjusted for inflation. See "Nominal Dollars" in Glossary.
[4] Distillate fuel oil and kerosene.
[5] Liquefied petroleum gases.
[6] Used for both space heating and ambiance.
Source: Table 2.5.

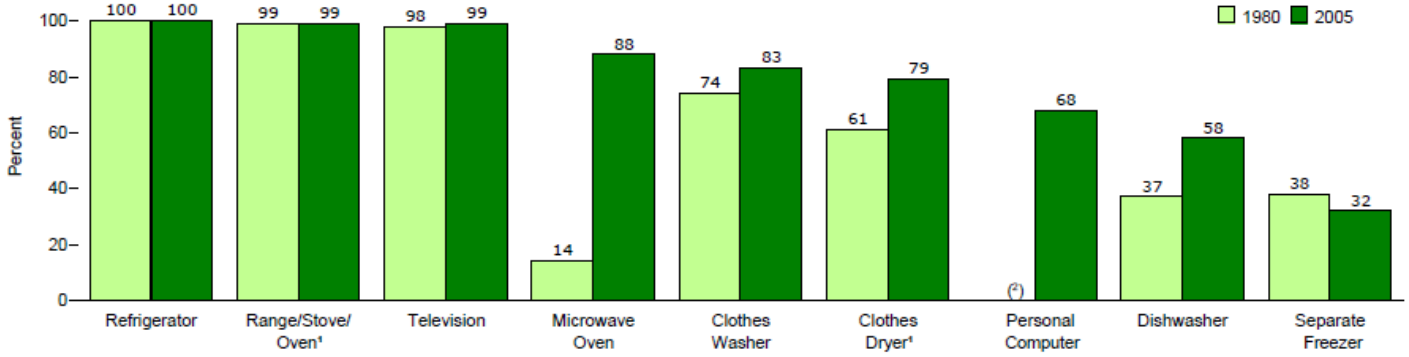
52 U.S. Energy Information Administration / Annual Energy Review 2009



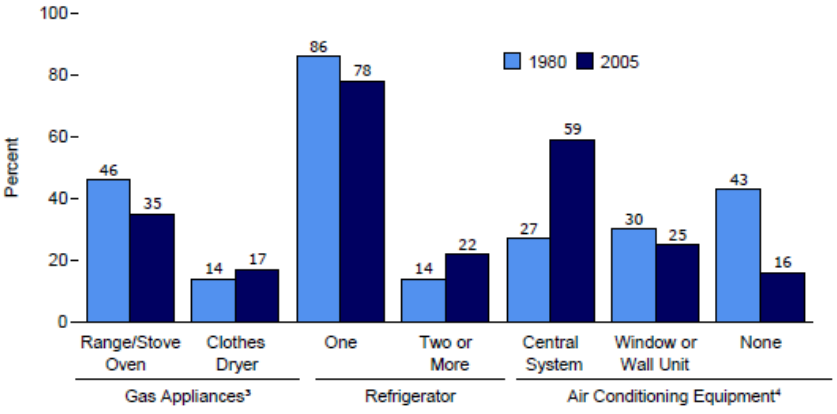
Residential Uses

Figure 2.6 Household End Uses: Fuel Types and Appliances

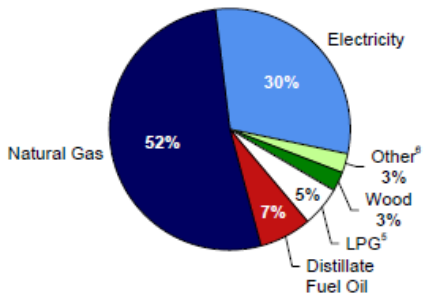
Share of Households With Selected Appliances and Electronics, 1980 and 2005



Share of Households With Other Selected Appliances, 1980 and 2005



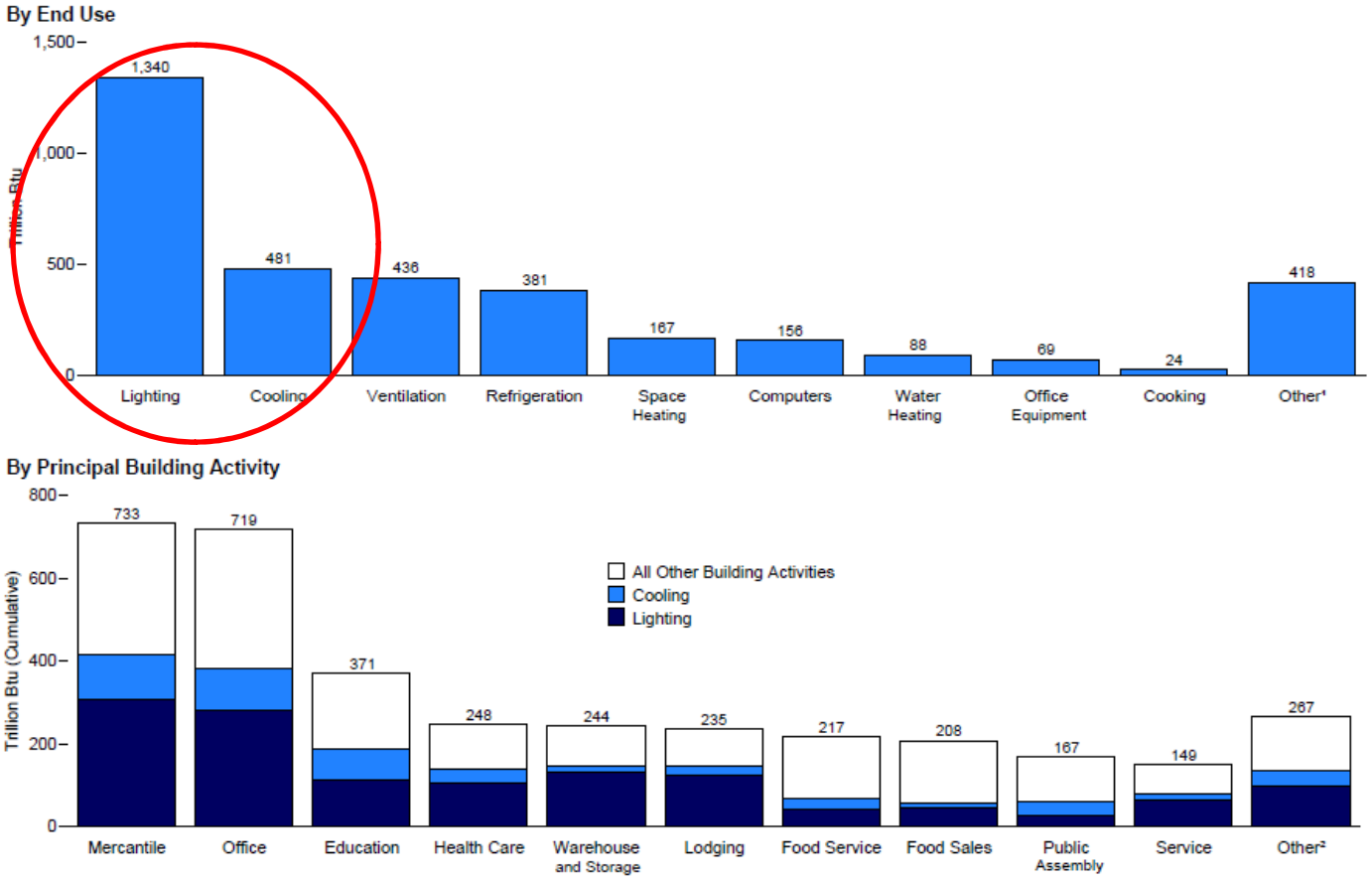
Space Heating by Main Fuel, 2005



[1] Natural gas and electric.
[2] Not collected in 1980.
[3] Natural gas or liquefied petroleum gases.
[4] Households with both central and individual room units are counted only under "Central."
[5] Liquefied petroleum gases.
[6] Kerosene, coal, solar, other fuel, or no heat.
Source: Table 2.6.

What Makes up Commercial?

Figure 2.11 Commercial Buildings Electricity Consumption by End Use, 2003



[1] Examples of "other" include medical, electronic, and testing equipment; conveyors, wrappers, hoists, and compactors; washers, disposals, dryers, and cleaning equipment; escalators, elevators, dumb waiters, and window washers; shop tools and electronic testing equipment; sign motors, time clocks, vending machines, phone equipment, and sprinkler controls; scoreboards, fire alarms, intercoms, television sets, radios, projectors, and door operators.

[2] Religious worship, public order and safety, vacant, and buildings that do not fit into any of the other named categories.

Note: Data are estimates for electricity consumption, excluding electrical system energy losses.

Source: Table 2.11.

Where to focus?

- Data points to the following:
- Residential http://www.energysavers.gov/ ← Good resource.
  - Space Heating & Air Conditioning
  - Water heating
  - Appliance Efficiency
- Commercial
  - Lighting
  - Cooling & Ventilation,
  - Refrigeration

4. Energy Efficiency

Building

Residential Efficiency Paths

Appliances & Electronics

- Buying Efficient Products
- Estimating Energy Use
- Turning Off Computers

Designing & Remodeling

- Passive Solar
- Cool Roofs
- Whole-House Design
- Ultra-Efficient Homes
- Log Homes
- Manufactured Homes
- Earth-Sheltered Homes

Electricity

- Reducing Electricity Use
- Buying Clean Electricity
- Making Clean Electricity
- Reading Electric Meters

Heating & Cooling

- Selecting & Replacing Your System
- Cooling Systems
- Heating Systems
- Heat Pumps
- Thermostats, Ducts, & Meters

Insulation & Air Sealing

- Weatherstripping & Caulking
- Insulation
- Controlling Moisture
- Ventilation

Landscaping

- For Your Climate
- For Your Microclimate
- Shading
- Using Windbreaks
- Conserving Water & Xeriscaping

Lighting & Daylighting

- Artificial Lighting
- Types of Lighting
- Turning Off Lights
- Natural Lighting

Water Heating

- Selecting a Water Heater
- Solar Water Heaters
- Demand (Tankless) Water Heaters
- Reducing Water Heating Bills
- Swimming Pool Heating

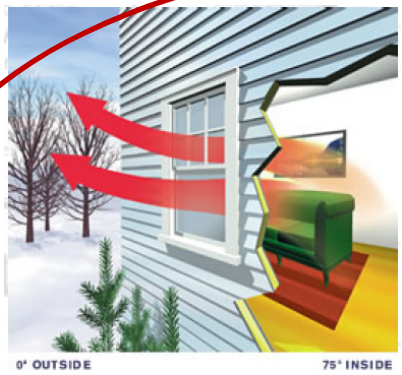
Windows, Doors & Skylights

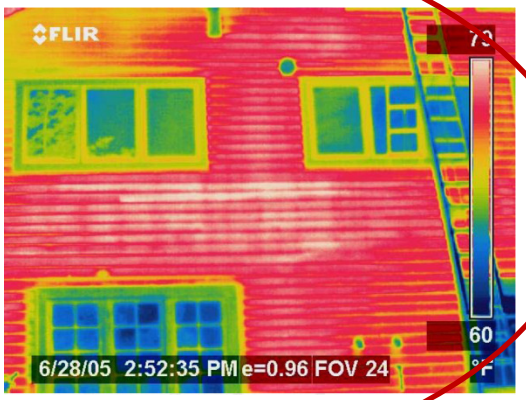
- Energy Performance Ratings
- Selecting Windows
- Selecting Exterior Doors
- Selecting Skylights

http://www.energysavers.gov/

Review of Heat Transfer

- Heat Moves in three ways
  1. Conduction
  2. Convection
  3. Radiation





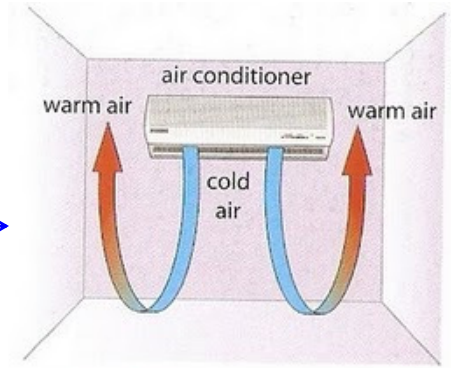
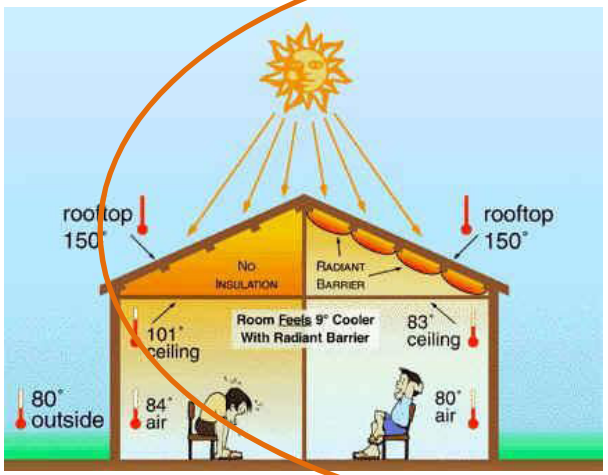
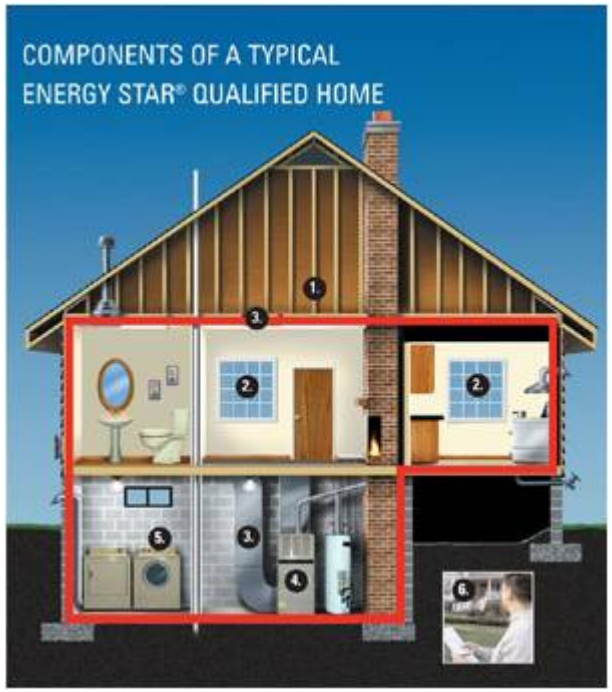


Figure 9.15 Convection currents in an air-conditioned room



Energy Star Qualified Home



http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_features

Energy Efficient Home Features

1. Effective Insulation
2. High-Performance Windows
3. Tight construction and ducts
4. Efficient heating and cooling equipment
5. Lighting and appliances
6. Third-party verification

In Almost Any Home:

The First Best Investment is to Maximize the Performance of the Building Envelope.

The Goal is to Reduce the amount of Energy it takes to HEAT and COOL the Dwelling while at the same time assuring that proper Indoor-Air-Quality is maintained.

or

to *Minimize* the

Demand Heating Load

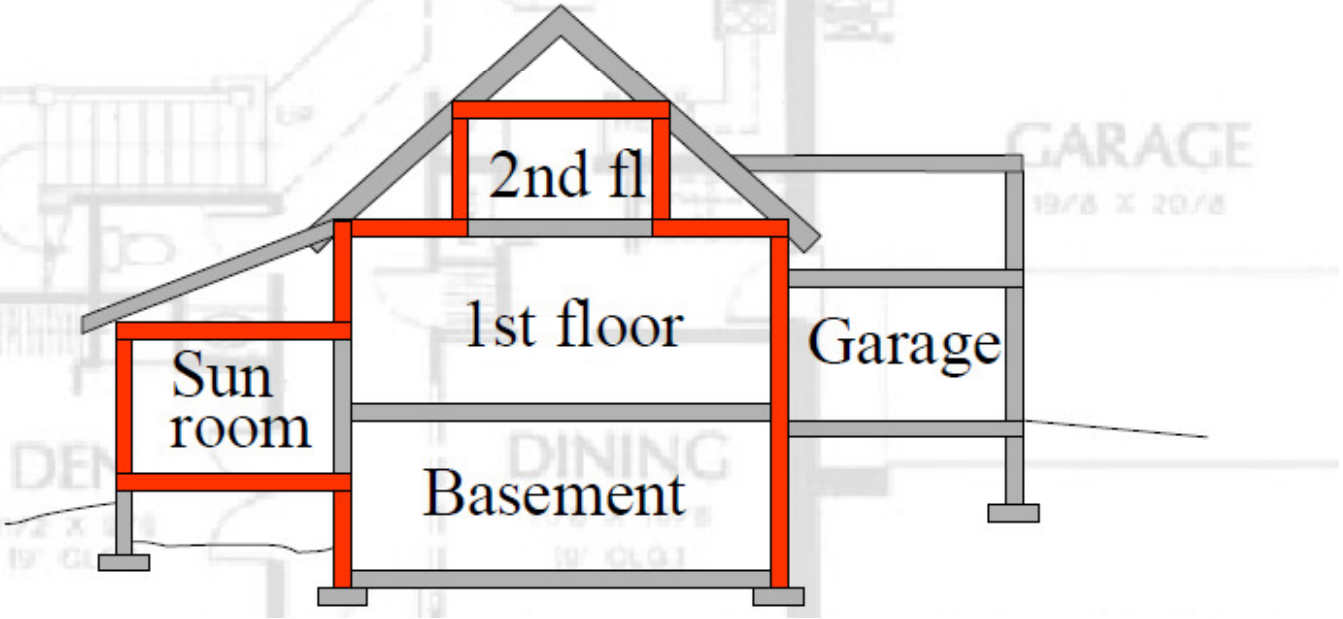
and the

DEMAND Cooling Load

of the Dwelling

→Definition: Building Envelope

- Components that separate conditioned spaces from outdoors, or unconditioned spaces



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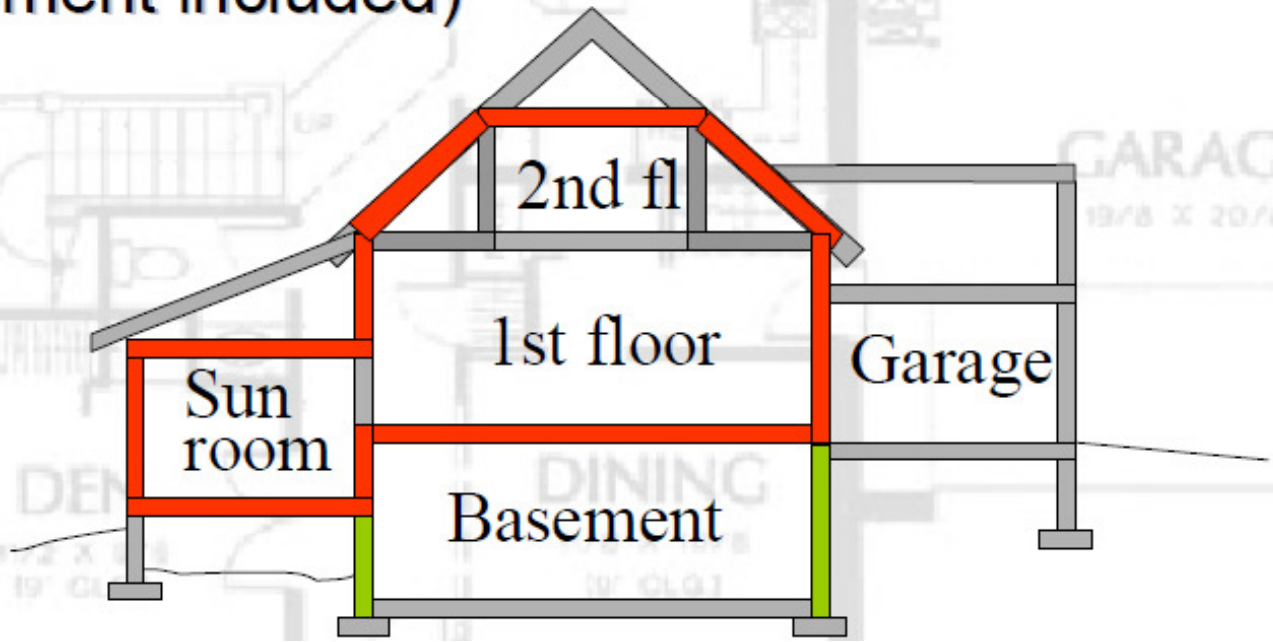
Building Envelope Example

- Same house, unconditioned basement (note wall between sunroom and basement included)



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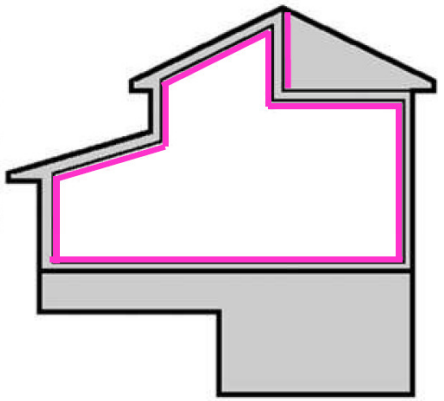
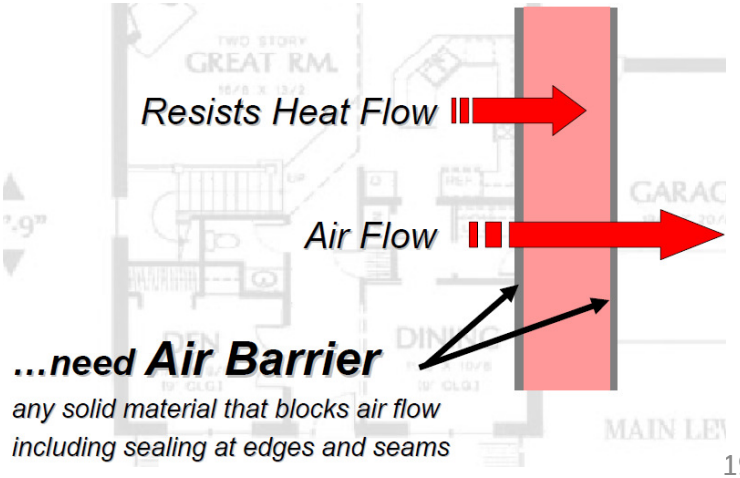
Insulation

•Insulation materials are rated according to their ability to resist heat flow.
• This thermal resistance rating is commonly known as an "R-value."
•The higher the R-value, the better the material is at resisting heat flow.

- Insulation is designed to slow down conductive heat loss through surfaces.
- Many different types of insulation.
- Each type has strong and weak points.
- All insulation can be effective if it is properly installed and coupled with a continuous air barrier.



•Continuous
•Full contact with interior air barrier
•Fully enclose the conditioned space



Common Insulation Materials

- Batt Fiberglass (Standard and High Density)
- Blown In Blanket (BIB) Fiberglass
- Batt Fiberglass and BIB Fiberglass or Cellulose Combo
- Blown-in Cellulose
- Sprayed On Cellulose
- Rigid Foam Board
- Rigid Foam Board and Batt FG or Cellulose Combo
- Sprayed On Foam (open cell or closed cell)
- Sprayed On Foam and Fiberglass or Cellulose Combo
- Insulated Panels "Stressed Skin"
- Structural Insulated Panels (SIPS)
- Insulated Concrete Form (ICF)

- Rock Wool
- Straw Bail Walls
- Recycled Blue Jeans
- Vermiculite, Pearlite, Sawdust, Seaweed, Newspapers, Corncobs, etc

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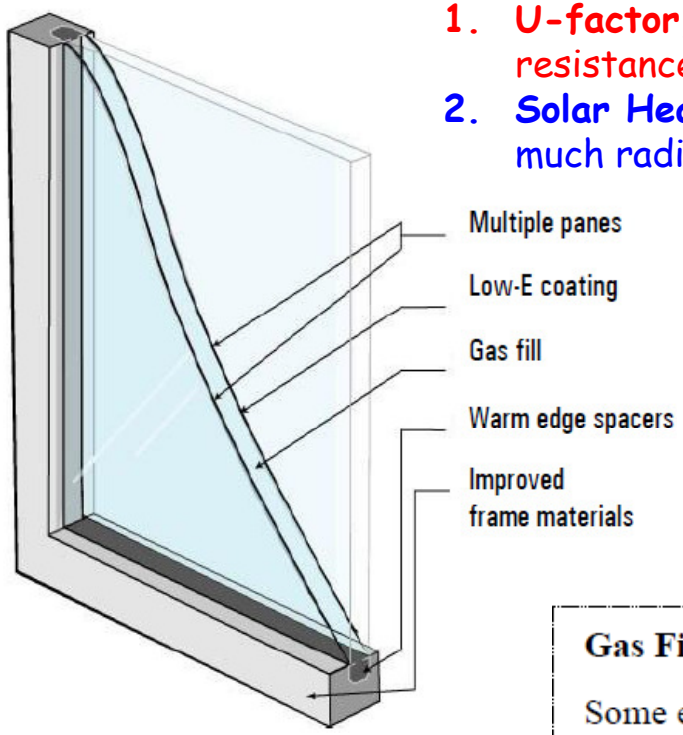
High-Performance Windows

The most important measurement numbers for windows are the

1. **U-factor**, which measures a window assembly's overall resistance to conductive and convective heat flow, and the
2. **Solar Heat Gain Coefficient (SHGC),** which measures how much radiant heat is coming through the window.



Low-E Glass

Special coatings reflect infrared light, keeping heat inside in winter and outside in summer. They also reflect damaging ultraviolet light, which helps protect interior furnishings from fading.

Multiple Panes

Two panes of glass, with an air or gas-filled space in the middle, insulate much better than a single pane of glass. Some Energy Star-qualified windows include three or more panes for even greater energy efficiency, increased impact resistance, and sound insulation.

Gas Fills

Some energy-efficient windows have argon, krypton, or other gases between the panes. These odorless, colorless, non-toxic gases insulate better than regular air.

Improved Frame Materials

Wood composites, vinyl, and fiberglass frames reduce heat transfer and help insulate better.

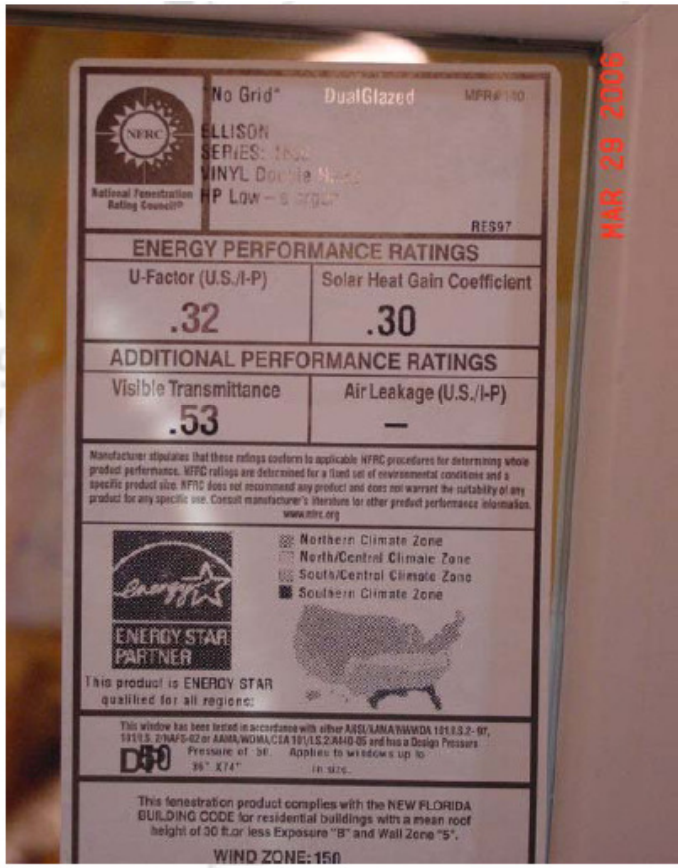
Warm Edge Spacers

A spacer keeps a window's glass panes the correct distance apart. Today's warm edge spacers—made of steel, foam, fiberglass, or vinyl—reduce heat flow and prevent condensation.

http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_features

High-Performance Windows

- Measured in u-value
- U-value means conductivity
- U-value and R-Value are mathematically inverse, two sides of the same coin.
- The lower the u-value the more efficient the window
- U-values have dropped dramatically in the last 10 years. The Average U-value in 1999 was about .50. (clear window) today the average is around .36 (low-e or low-e/argon)



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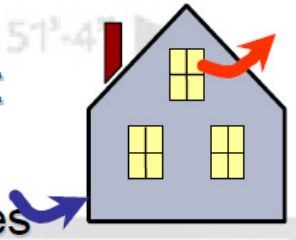
Tight Construction and Ducts

Air Leakage



- Applies to leakage points between:
  - Conditioned space and outside
  - Conditioned and unconditioned spaces
- Allow for differential expansion of dissimilar building materials; use sealants such as:
  - **Caulk:** silicone, urethane, foam, construction adhesive
  - **Gaskets:** polyethylene sill seal, EPDM, backer rod
  - **Tapes:** 3M Builder's tape, Tyvek tape (no duct tape)
  - **Housewrap** installed per manufacturer's instructions
  - **Blocking** where building cavities pass from conditioned to unconditioned space

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Tight Construction and Ducts

Air Sealing

- 30 Percent of heat loss in typical home due to random air leaks
- Most cost-effective way to save energy
- Air leakage major factor in moisture transport into building cavities and attics
- Fiberglass *does not* stop air leaks

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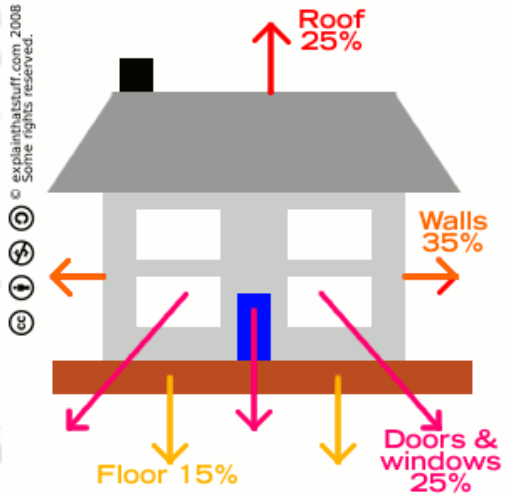
Tight Construction and Ducts

Air Leakage Points

- Door and window frames
- At foundation/sill
- Between wall and roof or ceiling; wall and floor; between wall panels
- Penetrations of utility services through wall, floor, ceiling/roof, wall plates
- Around/behind tubs and showers
- At access doors/hatches
- At recessed lights



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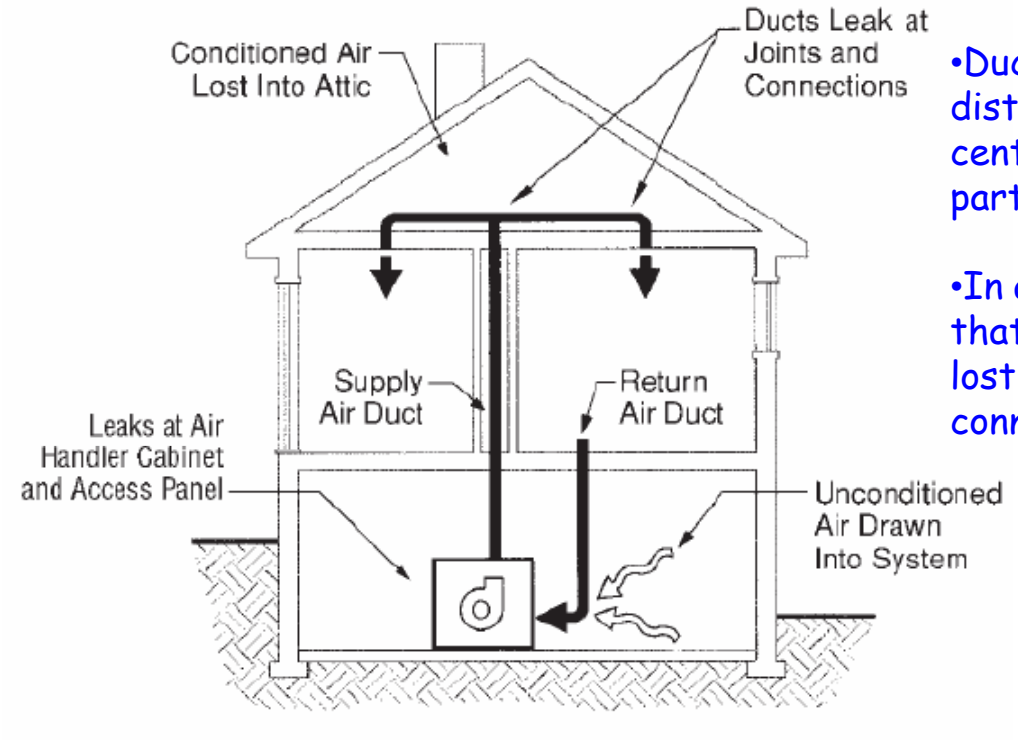
Tight Construction and Ducts

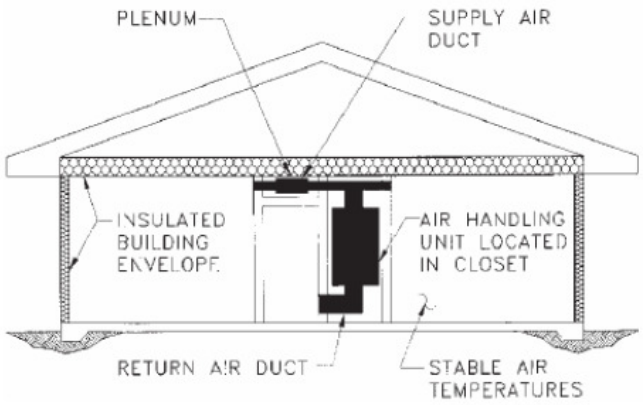


Typical Places Where Ducts Leak

- Ducts—known collectively as the air distribution system—carry air from the central heater or air conditioner to each part of the home and back again.
- In a typical house about 20% of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts.

http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_features

Ducts in Conditioned Spaces. Ducts operate more efficiently in conditioned air at room temperature. They do not work as well in excessively hot or cold attics and crawl spaces.



A Duct System Located in Conditioned Space

Third-Party Verification

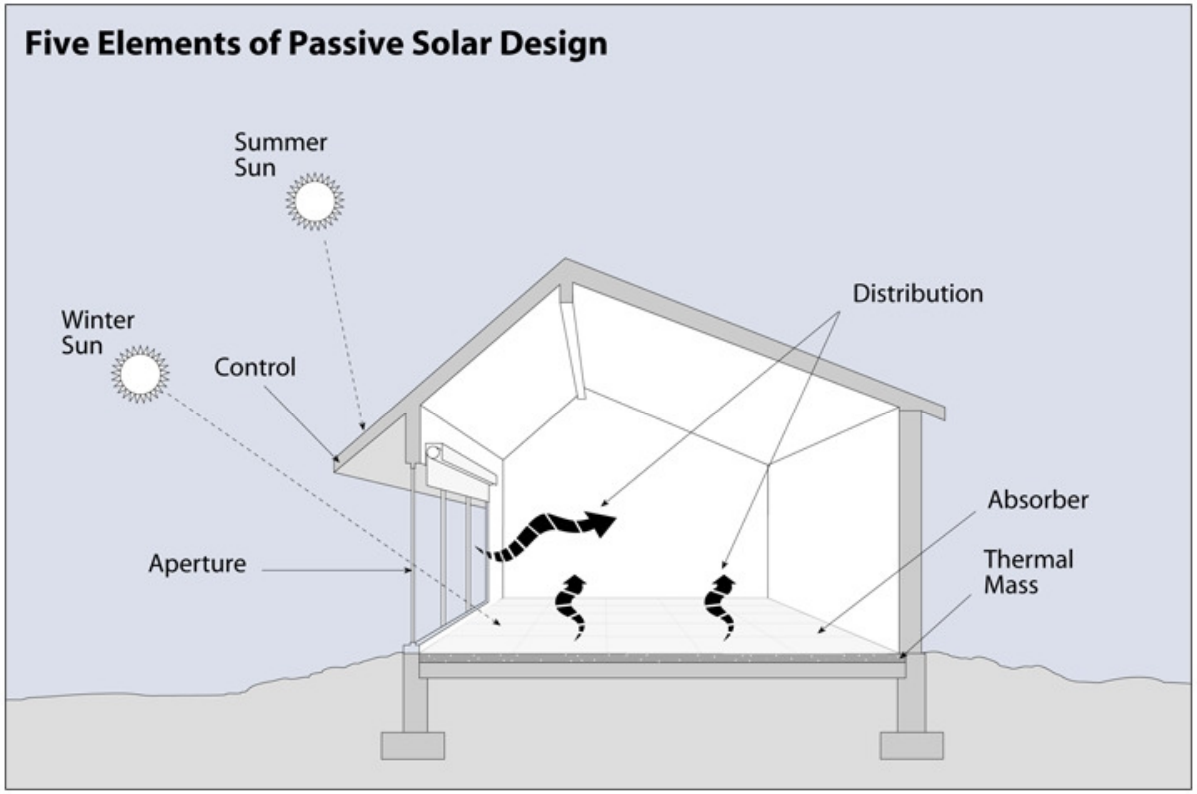
Home Energy Rater performs a blower door test.

http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_features

Look for the ENERGY STAR on the breaker box of your next home.

Technologies

Passive Solar Design



Control: Roof overhangs can be used to shade the aperture area during summer months.

Distribution: The method by which solar heat circulates from the collection and storage points to different areas of the house.

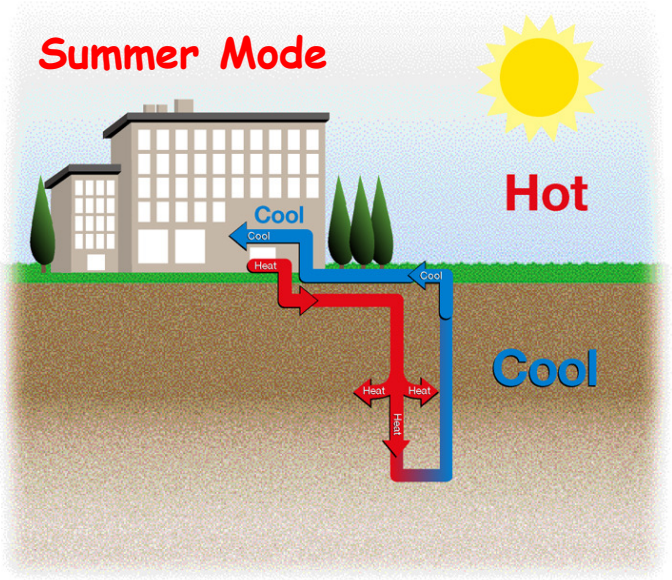
Thermal mass: Materials that retain or store the heat produced by sunlight.

Aperture (Collector): The large glass (window) area through which sunlight enters the building.

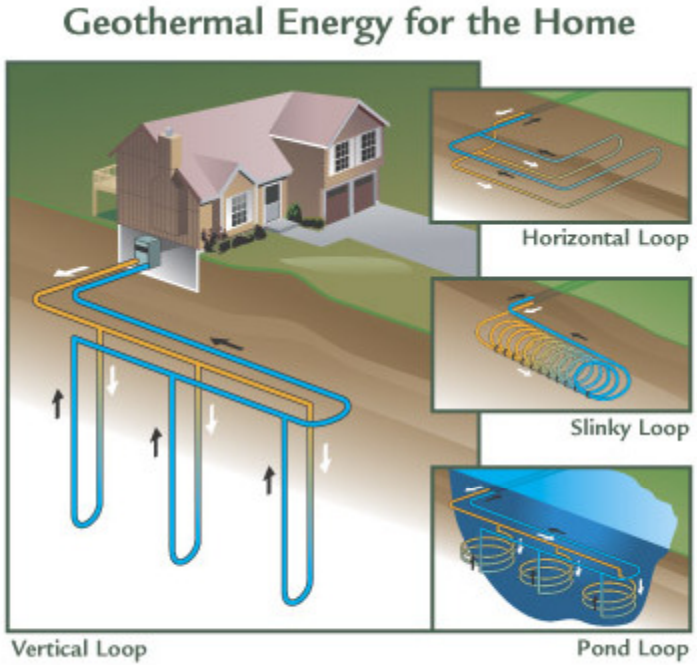
Absorber: The hard, darkened surface of the storage element which could be that of a masonry wall, floor, phase change material, or that of a water container—sits in the direct path of sunlight.

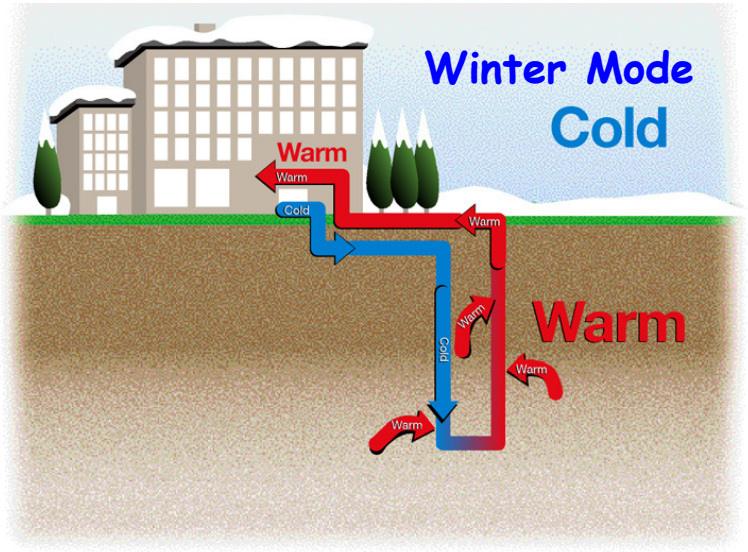
http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_features

Geothermal Heat Pump



HVAC System





GHP 125,200 BTU. 10 TON

Lighting

Look for **lumens (light output)** on the product packaging to determine appropriate wattage. For example, most 60-watt incandescent bulbs provide around 800 lumens.

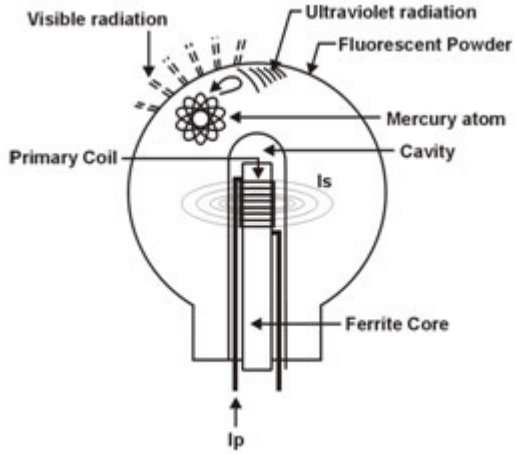
Luminous Efficacy

For this example the Lumens/Watt rating (or luminous efficacy) is 13.33 LPW= 800L/60W.

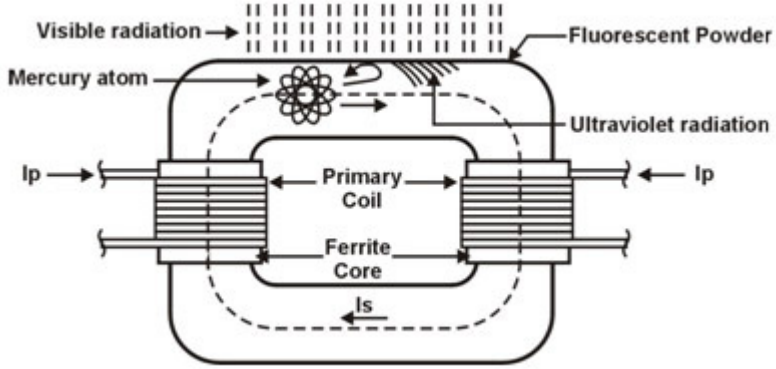
Category	Type	Overall luminous efficacy (lm/W)	Overall luminous efficiency[7]
Combustion	candle	0.3[11]	0.04%
	gas mantle	1–2[12]	0.15–0.3%
Incandescent	100–200 W tungsten incandescent (230 V)	13.8[13]–15.2[14]	2.0–2.2%
	100–200–500 W tungsten glass halogen (230 V)	16.7[15]–17.6[14]–19.8[14]	2.4–2.6–2.9%
	5–40–100 W tungsten incandescent (120 V)	5–12.6[16]–17.5[16]	0.7–1.8–2.6%
	2.6 W tungsten glass halogen (5.2 V)	19.2[17]	2.8%
	tungsten quartz halogen (12–24 V)	24	3.5%
	photographic and projection lamps	35[18]	5.1%
Light-emitting diode	white LED (raw, without power supply)	4.5–150 [19][20][21][22]	0.66–22.0%
	4.1 W LED screw base lamp (120 V)	58.5–82.9[23]	8.6–12.1%
	6.9 W LED screw base lamp (120 V)	55.1–81.9[23]	8.1–12.0%
	7 W LED PAR20 (120 V)	28.6[24]	4.2%
	8.7 W LED screw base lamp (120 V)	69.0–93.1[23][25]	10.1–13.6%
Arc lamp	xenon arc lamp	30–50[26][27]	4.4–7.3%
	mercury-xenon arc lamp	50–55[26]	7.3–8.0%
Fluorescent	T12 tube with magnetic ballast	60[28]	9%
	9–32 W compact fluorescent	46–75[29][30][14]	8–11.45%[31]
	T8 tube with electronic ballast	80–100[28]	12–15%
	PL-S 11W U-tube with traditional ballast	82[32]	12%
	T5 tube	70–104.2[33][34]	10–15.63%
	Spiral tube with electronic ballast	114-124.3[35]	15–18%
Gas discharge	1400 W sulfur lamp	100[36]	15%
	metal halide lamp	65–115[37]	9.5–17%
	high pressure sodium lamp	85–150[14]	12–22%
	low pressure sodium lamp	100–200[38][39][14]	15–29%

http://en.wikipedia.org/wiki/Luminous_efficacy

Lighting



Cavity-type Induction Lamp



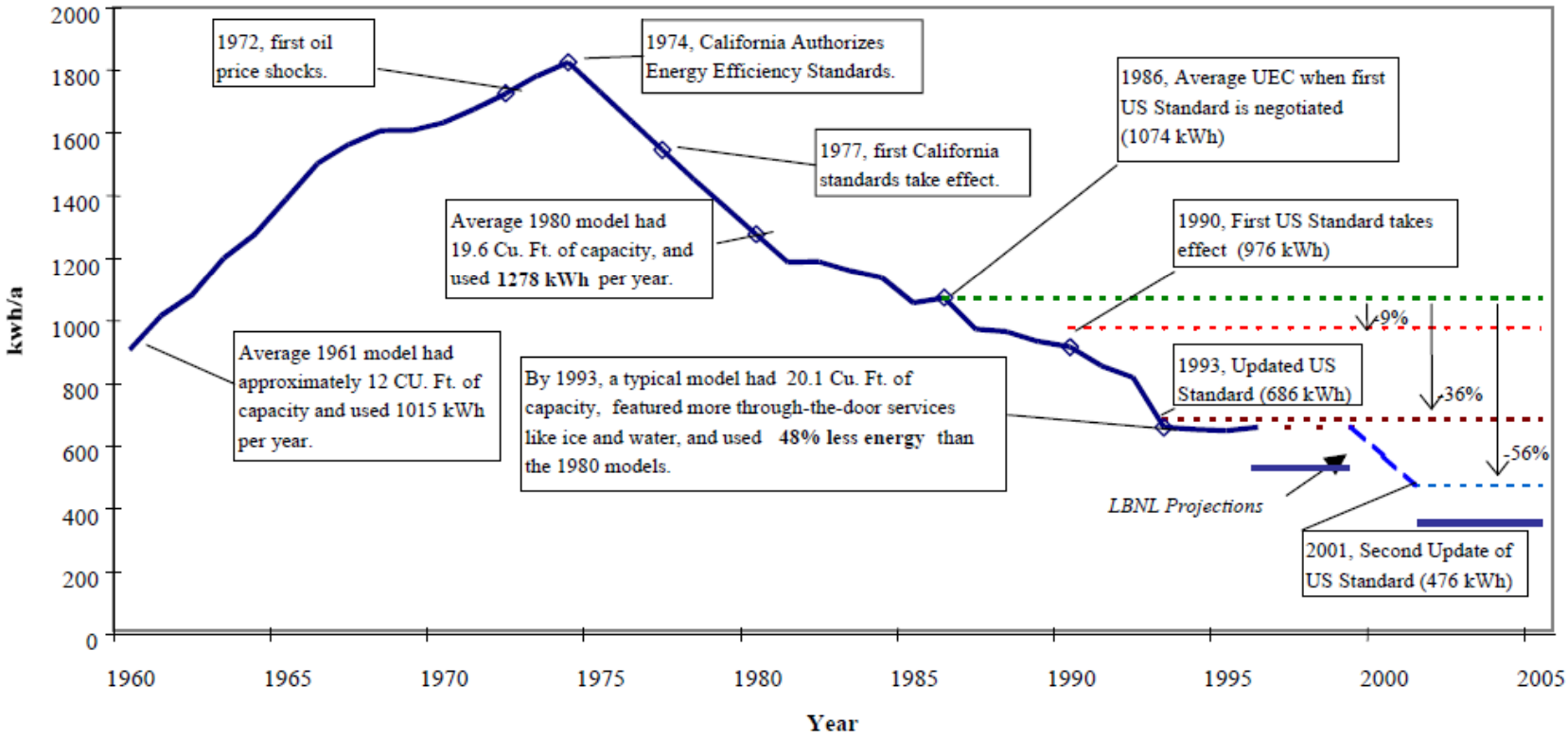
External Coil Induction Lamp

	LPW	Rated Hour	CRI	Ignition Time	Color Temp.	Major Drawback
Incandescence	11 - 15	1.5K - 5K	40	instant		Very Inefficient – Short Life
MercuryVapor	13 - 48	12 - 24K		2 - 15 min	4000	Inefficiency
HPS	45 - 110	12 - 24K	25	2 - 15 min	2000	Low CRI
LPS	80 - 180	10 - 18K	0	2 - 15 min.	1800	Low CRI
Metal Halide	60 - 100	10 - 15K	75	2 - 15 min.	3000-4300	High Maintenance
Induction Lamp	61 - 76	100 – 120K	82	.05 sec.	2600-6500	Relatively High Initial Cost.

Typical Industrial Highbay Fixture with Round 200W Induction Lamp.

Refrigerator Energy Consumption

(Average energy consumption of new refrigerators sold in the U.S.)



Savings: ~1400 kWh/year * $0.10/kWh = $140/yr per household

***100 M households = $14 B/year** Sam Baldwin, FESC Summit, September 2009

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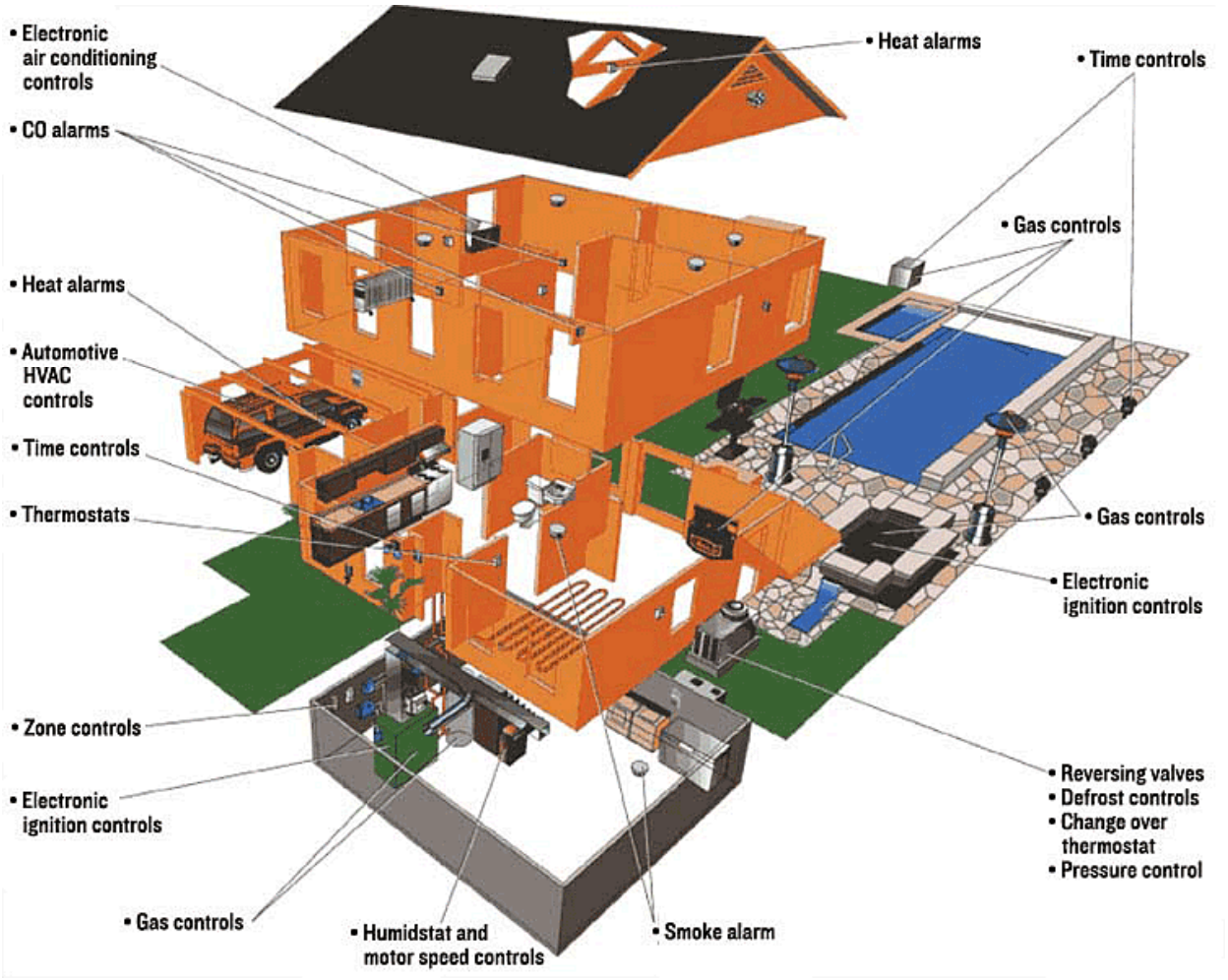
Source: LBNL

Home Energy Savings Network



Home Energy Savings Network

These smart meters serve as a gateway for Home Area Networks (HANs) of wireless devices such as ZigBee thermostats, load control devices, in-home displays, and smart appliances.

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio.