

## Energy Conservation

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## Outline

- What is energy conservation?
- Main energy consumption applications that are candidates for conservation
- Energy conservation technology
- Energy conservation standards
- Will not consider transportation energy to be discussed later

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## What is Goal?

- Generally seek to reduce use of conventional fuels, especially fossil fuels, for environmental and long-term availability concerns
- Have discussed alternative energy supplies that will allow this
- All types of conservation also provide reduction in energy use

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## What is Energy Conservation?

- Doing same task with greater efficiency
  - E. g. improved technology for more efficient electric motors
- Applying existing technology with high first cost, but lower life-cycle cost
  - E.g. home insulation
- Life-style changes
  - E.g. using smaller cars, mass transit or simply driving less
- Electric power cost savings?

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## Accomplishing Conservation

- Market forces
  - Rising energy costs prompt consumers to choose more efficient technology
  - Changes take place over time
  - Assumes consumers are informed and have the financial means to afford an item that usually has a higher initial cost
    - Some markets, such as housing, driven by first price may not take full advantage of conservation technologies absent regulations

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## Accomplishing Conservation II

- Efficiency standards
  - Mandate efficiency in products (appliance efficiency, building standards, etc.)
- Consumer notification requirements
  - Labels on home appliances and cars
- Energy Star
  - Industries voluntarily meet performance standards that allow them to display logo for merchandising

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### Accomplishing Conservation III

- Taxes or fees
- Artificially increase the cost of energy to stimulate consumer behavior
  - Popular in economic theory
  - Not popular with individuals in US
  - Question of what to do with fee income
  - Used in Europe to keep transportation fuel costs high to stimulate more fuel efficient vehicles
- Rationing?

### Rationing Gasoline?

- Considered, but never used in 1970s
- Coupons designed for this use



### Accomplishing Conservation IV

- Life-style changes
  - Can be result of market forces or fees
    - Higher costs lead to changes in personal choices about energy use
  - Politically controversial
    - Some people believe that individuals have a moral obligation to reduce energy use
    - Others believe that individuals should have freedom of choice in their economic decisions
    - DOE has energy efficiency division, but no energy conservation division

### Effect of Standards

- Many different standards at State and Federal levels for new equipment and building construction
- Success limited by long lives of equipment and buildings
- High efficiency technology is cost effective over life cycle
- What is cost-effectiveness for replacing existing equipment?

Based on standard U.S. Government tests

## ENERGYGUIDE

Refrigerator-Freezer  
With Automatic Defrost  
With Side-Mounted Freezer  
Without Through-the-Door-Ice Service

XYZ Corporation  
Model ABC-W  
Capacity: 23 Cubic Feet

**Compare the Energy Use of this Refrigerator with Others before You Buy.**

This Model Uses 776 kWh/year	
Uses Least Energy 742	Uses Most Energy 836

**Refrigerators using more energy cost more to operate. This model's estimated yearly operating cost is:**

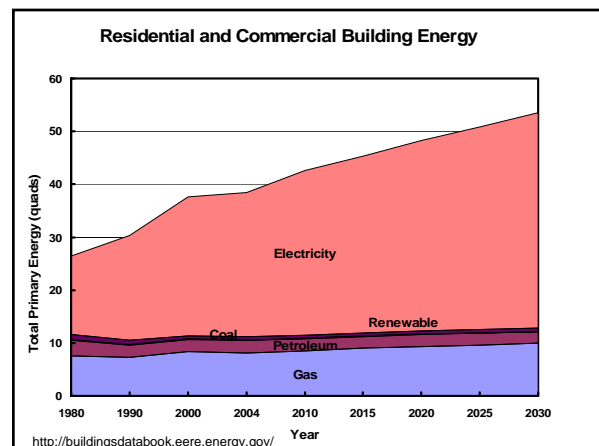
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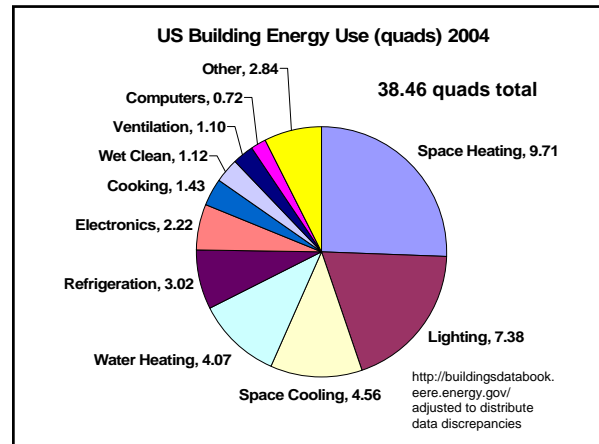
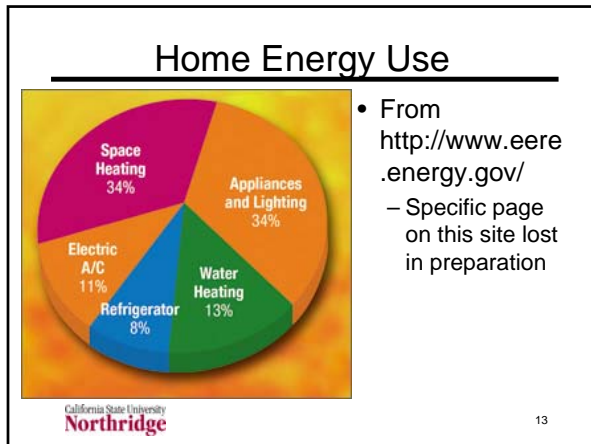
Based on a 1995 U.S. Government national average cost of 8.4¢ per kWh for electricity. Your actual operating cost will vary depending on your local utility rates and your use of the product.  
Important: Remove the label before consuming produce as a violation of Federal law (16 U.S.C. 8102).

### Label

Provides information to consumers

- Size may be difference
- Cost range will be \$62 to \$70 for these refrigerators

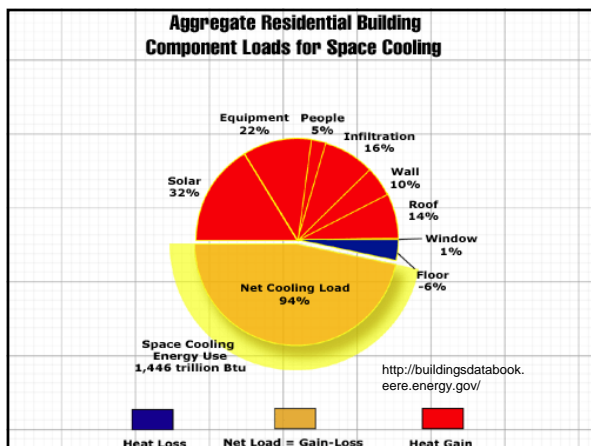
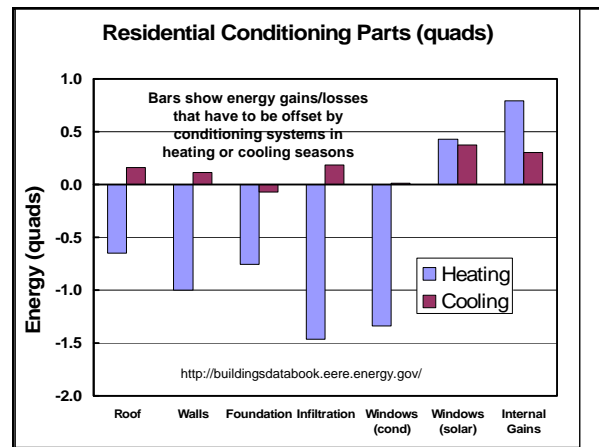




### US Building Energy Use

Year	Gas	Oil	Coal	Renew	Electric
1980	7.52	3.04	0.15	0.87	26.43
1990	7.22	2.36	0.16	0.74	30.40
2000	8.35	2.32	0.10	0.61	37.66
<b>2004</b>	<b>8.13</b>	<b>2.36</b>	<b>0.10</b>	<b>0.55</b>	<b>38.46</b>
2010	8.51	2.25	0.10	0.59	42.57
2015	8.98	2.25	0.10	0.59	45.37
2020	9.36	2.22	0.10	0.60	48.26
2025	9.64	2.17	0.10	0.60	50.79
2030	9.93	2.14	0.10	0.60	53.47

<http://buildingsdatabook.eere.energy.gov/>



### Building Conditioning

- Reducing primary energy required for winter heating and summer cooling
  - Insulation of walls and attics
  - Sealing and insulating air ducts
  - More efficient furnaces and air conditioning units
  - Programmable thermostats
  - Life style: how hot/cold should your house be in winter/summer?

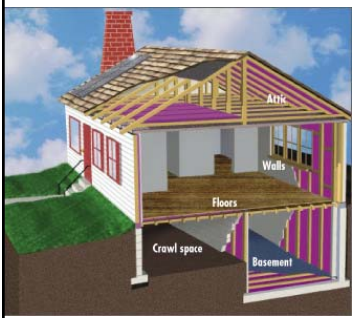
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### Human Comfort

- Bodies give off heat depending on level of work performed
- Cooling by evaporation and heat transfer
  - Heat transfer is by convection with room air and radiation with room walls
  - Insulation changes wall temperatures inside rooms giving greater comfort for the same air temperature (thermostat setting)

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### Where to Insulate



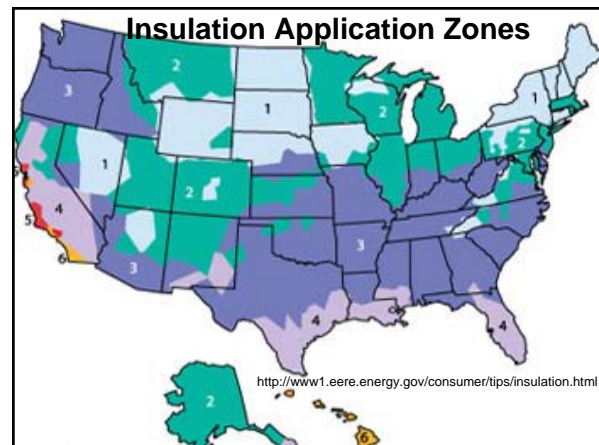
- Most homes built before 1980 have no insulation
- Retrofitting is cost effective
- New homes all have insulation

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[http://www1.eere.energy.gov/consumer/tips/insulation\\_sealing.html](http://www1.eere.energy.gov/consumer/tips/insulation_sealing.html)

### What is an R-value?

- Measure of thermal resistance
- $Q = \Delta T/R$ 
  - Higher R values give less heat transfer for a given temperature difference
- For conduction  $R = L/k$ 
  - L is thickness in ft
  - k is thermal conductivity in Btu/h-ft<sup>2</sup>·°F
- Can also apply to radiation heat transfer
- R units are always h-ft<sup>2</sup>·°F/Btu

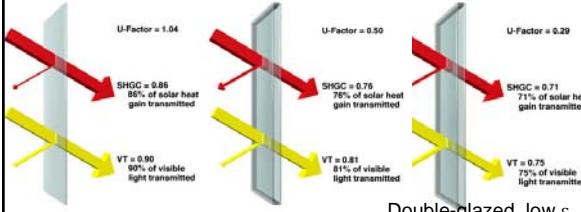
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<http://www1.eere.energy.gov/consumer/tips/insulation.html>

Zone	Gas	Heat pump	Fuel oil	Electric furnace	Ceiling			Floor	Crawl space (B)	Slab edge	Basement	
					Attic	Cathedral	Wall (A)				Interior	Exterior
1	✓	✓	✓		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
1				✓	R-49	R-60	R-28	R-25	R-19	R-8	R-19	R-15
2	✓	✓	✓		R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
2				✓	R-49	R-38	R-22	R-25	R-19	R-8	R-19	R-15
3	✓	✓	✓	✓	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
4	✓	✓	✓		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
4				✓	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
5	✓				R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
5		✓	✓		R-38	R-38	R-13	R-13	R-19	R-4	R-11	R-4
5				✓	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10
6	✓				R-22	R-22	R-11	R-11	R-11	(C)	R-11	R-4
6		✓	✓		R-38	R-30	R-13	R-11	R-13	R-4	R-11	R-4
6				✓	R-49	R-38	R-18	R-25	R-19	R-8	R-11	R-10

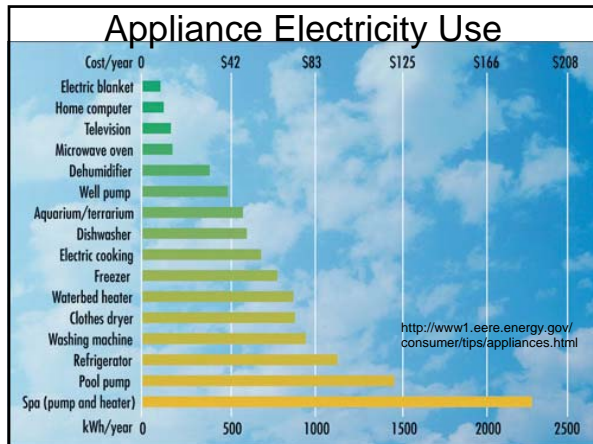
### Window Technology



Single-glazed, clear    Double-glazed, clear with Ar or Kr gas fill

- U is overall heat transfer coefficient
- $Q_{\text{to outside}} = UA(T_{\text{room}} - T_{\text{ambient}})$

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<http://www.efficientwindows.org/gtypes.cfm>



### Energy Conservation Law

- Bills enacted by Congress placed in US Code of Laws
- Title 42 – the public health and welfare
  - Chapter 77 – Energy conservation
    - Starts with statement of congressional intent and definition section
    - Has four subchapters; Subchapter III is titled "Improving Energy Efficiency"
    - [http://www.law.cornell.edu/uscode/html/uscode42/uscode\\_sup\\_01\\_42\\_10\\_77\\_20\\_III\\_30\\_A.html](http://www.law.cornell.edu/uscode/html/uscode42/uscode_sup_01_42_10_77_20_III_30_A.html)

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### Federal Regulations

- Laws can set standards, authorize a government agency (e.g. DOE) to set standards, or both
  - Often law contains initial set of standards with authority for agency to revise
  - Listed in **Code of Federal Regulations**
  - Rulemaking process in *Federal Register*
  - Final rules in Title 10 Energy
  - <http://www.gpoaccess.gov/cfr/index.html>
  - [http://www.eere.energy.gov/buildings/appliances\\_standards/](http://www.eere.energy.gov/buildings/appliances_standards/)

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### Block Grant Program

- Funded by 2009 Stimulus Act (HR 1)
  - \$2.7 billion block grants to states, cities, ...
  - \$455 million by competitive grants
  - Block grant purposes
    - Efficiency/Conservation Strategy
    - Residential/Commercial Building Energy Audits
    - Incentive Programs for energy efficiency
    - Grants for Energy Efficiency Retrofits
    - Buildings/Facilities Efficiency/Conservation
    - Transportation Programs to conserve energy.
    - Building Codes and Inspections to promote building energy efficiency.

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### Block Grant Program II

- Building Codes/Inspections to energy efficiency
- Energy Distribution Technologies
- Material Conservation Programs
- Reduction and Capture of Methane and Greenhouse Gases
- Energy efficient Traffic Signals/Street Lighting.
- Renewable Energy Technologies on Government Buildings.
- Any Other Appropriate Activity
- Assessment metrics
- Reference <http://www.eecbg.energy.gov/>

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### Block Grant Assessment

- Grantees will be required to report regularly to the DOE on five metrics
- Jobs created and/or retained
- Energy savings on a per dollar invested basis
- Renewable energy capacity installed
- Greenhouse gas emissions reduced
- Funds leveraged

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### Net-Zero-Energy Buildings

- DOE research initiative started in 2008
  - Net-zero site energy
  - Net zero source energy – accounts for transmission losses
  - Net zero energy costs
  - Net zero energy emissions
  - Net zero energy – produces at least 75% of its energy on-side using renewables
- Collaborative research partnership

### Net-Zero Energy Research

- Commercial lighting
- Indoor environmental quality
- Building controls and diagnostics
- Space conditioning
  - Peak-load shifting
  - Dedicated outdoor air supply/heat recovery
  - Radiant heating or cooling
  - Low lift vapor compression cooling
  - Advanced HVAC controls

### Net-Zero Buildings Database

- <http://zeb.buildinggreen.com/>
- Describes in detail various buildings
- Example is Audubon Center at Debs park in Los Angeles
  - Not connected to grid
  - Uses photovoltaics with battery backup
  - Has small engine to charge batteries in case of long series of days without sun
  - Passive solar and fresh-air design

### Appliance Standards

- Energy Policy and Conservation Act of 1975 (EPCA) set deadlines for DOE to set energy efficiency standards for residential and commercial products
- National Appliance Energy Conservation Act (1988)
  - Congress set standards with a schedule for DOE review and change
  - Preempted state standards
    - States can have standards that are the same as Federal standards
    - States can petition to have stricter standards, but it is difficult to have a petition approved
    - *E.g.* denial of California petition for washing machines (71 Federal Register 78157-78168, December 28, 2006)
- 2005 DOE sued for not issuing standards

### Appliance Standards II

- November 2006 consent decree: DOE to set all standards by June 30, 2011
- Energy Independence and Security Act of 2007 (EISA): DOE to establish standards for additional products
- Presidential memorandum, February 5, 2009 requests DOE to accelerate process for standards

### Refrigerator Standards

- Adjusted volume,  $AV = (\text{Fresh Food Volume}) + 1.63 \times (\text{Frozen Food Volume})$
- Adjusts total actual volume to account for greater cooling demands in freezer
  - Eighteen product classes
  - Standard is in terms of maximum annual energy use in standard tests conditions
    - *e. g.*:  $10.10AV + 406.0$  kWh/yr for side mounted freezer with ice through the door
- Energy Star is 15% more efficient

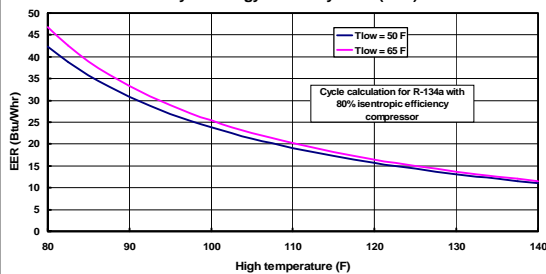
### Furnace Standards

- DOE has proposed a standard furnace efficiency of 80%
  - Standard is Annual Fuel Use Efficiency (AFUE) over heating season
  - Criticized as being late (due in 1994) and not as effective as possible
  - DOE has invited states to submit their own standards for preemption if based on local heating requirements
    - Higher standards more cost effective in colder climates

### SEER

- Seasonal Energy Efficiency Ratio
  - Similar to EER: cooling capacity in Btu/h divided by electrical input in watts
  - SEER requires measurements over different operating conditions to measure average EER over a typical cooling season
    - [http://www.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/central\\_ac\\_tp\\_2005.pdf](http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/central_ac_tp_2005.pdf)  
[http://www.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/central\\_ac\\_tp\\_2005.pdf](http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/central_ac_tp_2005.pdf)

Cycle Energy Efficiency Ratio (EER)



- Does not account for fan power and heat losses to surroundings
  - Current standard is 13 Btu/kWh

### California Standards

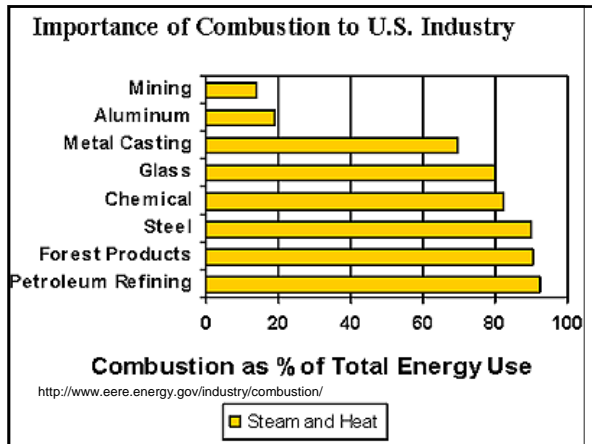
- Established during 1970s
- Implemented by the California Energy Commission
- Preempted by established Federal standards
- Building standards
  - Residential and commercial buildings
- Appliance Standards
  - Residential and commercial equipment

### Rate Your Energy Use

- See Energy Star web site
- [http://www.energystar.gov/index.cfm?fu\\_seaction=home\\_energy\\_yardstick.show\\_step2](http://www.energystar.gov/index.cfm?fu_seaction=home_energy_yardstick.show_step2)
- Enter data on annual energy use (gas and electric) and costs
- Also asks for data on construction date, conditioned area, and number of residents

### Industrial Conservation

- Market forces work well here
- Investments in energy conservation following 1973 oil embargo had large payoff in early 1980s
  - Long time required for increased costs to effective in reducing energy consumption
- Have many specific process improvements for different industries
- Combustion improvements



### Environmental/Energy Balance

- High efficiency combustion processes produce higher temperatures
- Higher temperatures increase NOx emissions
- Main focus of research has been to improve combustion efficiency while decreasing NOx emissions
- Done by control of air/fuel mixing in combustor