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

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

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?

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

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
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?

Label

- Provides information to consumers
  - Size may be difference
  - Cost range will be $62 to $70 for these refrigerators
Home Energy Use

- From http://www.eere.energy.gov/
  - Specific page on this site lost in preparation

US Building Energy Use

| Year | Gas | Oil | Coal | Renew | Electric |
|------|-----|-----|------|-------|----------|
| 1990 | 7.45| 3.04| 0.16 | 0.50  | 26.43    |
| 2000 | 8.35| 2.32| 0.10 | 0.61  | 37.66    |
| 2004 | 8.13| 2.36| 0.10 | 0.55  | 38.46    |
| 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    |

Bar chart showing energy gains/losses that have to be offset by conditioning systems in heating or cooling seasons.

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
  - Lifestyle: how hot/cold should your house be in winter/summer?
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)

Where to Insulate

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

What is an R-value?

- Measure of thermal resistance
- \( Q = \frac{\Delta T}{R} \)
  - Higher R values give less heat transfer for a given temperature difference
- For conduction \( R = \frac{L}{k} \)
  - \( L \) is thickness in ft
  - \( k \) is thermal conductivity in Btu/h·ft²·°F
- Can also apply to radiation heat transfer
- R units are always h·ft²·°F/Btu

Insulation Application Zones

Window Technology

- Single-glazed, clear
- Double-glazed, clear
- Double-glazed, low ε with Ar or Kr gas fill
- U is overall heat transfer coefficient
- \( Q_{\text{outside}} = UA(T_{\text{room}} - T_{\text{ambient}}) \)
Appliance Electricity Use

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/usc_sup_01_42_10_77_20_III_30_A.html

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/appliance_standards/

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.

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/

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
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 do 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 = (Fresh Food Volume) + 1.63 x (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

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?fuseaction=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

Importance of Combustion to U.S. Industry

Environmental/Energy Balance

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