Economic Issues of Energy Efficiency

CEE 320

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U.S. Energy Usage: 2005

Source: EIA, Annual Energy Review

- Petroleum Products: 40 Quadrillion Btu
- Coal: 23 Quadrillion Btu
- Natural Gas: 23 Quadrillion Btu
- Nuclear Electric Power: 8 Quadrillion Btu
- Hydroelectric Power: 3 Quadrillion Btu
- Biomass: 3 Quadrillion Btu
- Geothermal Energy: 0.4 Quadrillion Btu
- Solar Energy: 0.06 Quadrillion Btu
- Wind Energy: 0.15 Quadrillion Btu
World Energy Production and Use: 2004
(About 440 Quad Total)

Source: EIA, Annual Energy Review
Energy Consumption Per 2000 Dollar of GDP

Source: EIA, Annual Energy Review
Trends in U.S. Sectoral Energy Use

Quadrillion Btu

- Residential
- Commercial
- Industrial
- Transportation: Primary

Years:
- 1950
- 1955
- 1960
- 1965
- 1970
- 1975
- 1980
- 1985
- 1990
- 1995
- 2000
- 2005
U.S. Sectoral Energy Use: 2005

Consuming Sector
- Residential
- Commercial
- Industrial
- Transportation

Quadrillion Btu
- Electricity (Incl losses)
- Hydro, Solar, Geothermal
- Biomass
- Coal
- Natural Gas
- Petroleum
US Primary Energy and Electricity Use by Sectors

Through Electricity: Res, Ind, Comm
Primary: Res, Ind, Comm
Transportation: Primary
Fundamental Differences Among Sectors

- **Transportation**
  - Virtually all primary energy used directly
  - Dominated by oil
- **Residential and Commercial**
  - Well more than one half of energy used through electricity
- **Industrial Use**
  - Very diverse usage patterns
- **Electric Generation**
  - Virtually complete ability to substitute among primary energy sources
Energy Efficiency:
Economically Efficient Reductions in Energy Use Intensity
Increased Economic Efficiency

Decreased Energy Use

Reduced Economic Efficiency

Increased Energy Use
Economically Efficient Energy Intensification

Inefficient Energy Saving

Energy Efficiency Improvement

Waste

Economically Efficient Energy Intensification

Decreased Energy Use

Increased Economic Efficiency
Some Sources of Efficiency Failures

- Externalities of Energy Use
  - Global Climate Change
  - Risks of Energy Price Shocks
  - Limitations on our Foreign Policy Options
  - Terms of Trade Impacts (Pecuniary “Externalities”)
  - Safety externalities: heavier cars transfer injury risk during accidents to the other car

- Pricing Below Marginal Cost
  - Non-time-differentiated Electricity Pricing

- Information Imperfections and Asymmetries
  - Consumer Product Marketing (e.g. automobile marketing)
  - New Building Construction
  - Poor information (How many consumers understand appliance energy costs?)

- Incomplete Technology Options
  - Under-investment
  - Sub-optimal technology directions, due to externalities

- Non-Convexities
  - Learning By Doing Technology Spillovers
  - “Chicken and Egg” Problems
Decreased Energy Use

- Restrict SUV Sales
- Gasoline Rationing
- Overly Strict Building Standards
- Plug-In Hybrids (Now)
- Hybrid Gas-Electric Vehicles
- LED General Lighting (Future)
- “Smart” Local Land Development
- Energy Audits
- Tighter CAFE Standards
- Energy Star Labeling
- Congestion Pricing
- LED Traffic Lights
- Compact Fluorescent Penetration
- Some Rapid Transit Systems
- “Smart Buildings” Controls
- Pigouvian Energy Tax
- Optimized Building Construction
- Some Rapid Transit Systems
- Economic development
- Internet Growth
- Economic development
- Personal Computer Penetration
- Airline Deregulation
- Rural Electrification
- Internet Growth
- LED General Lighting (Now)
- Hybrid Gas-Electric Vehicles
- LED General Lighting (Future)
- Plasma TVs
- Gasoline Price Controls
- Many Rapid Transit Systems
- Promote Incan-descent Lighting
- Many Rapid Transit Systems
Two Historical Examples
Trends in Refrigeration Energy Use

Per Capita Electricity Consumption

United States

California

1974

Source: http://www.eia.doe.gov/emeu/states/sep_use/total/csv/use_csv.html
Residential, Commercial
Forces Shaping Energy Use

• Residential and Commercial Sector
  • Building Characteristics
    • Size
    • Lighting, heating, cooling technologies
    • Insulation
  • Energy Management
    • Thermostat settings
    • Lighting levels chosen
  • Plug power
    • Appliance saturation
    • Vintage of Refrigeration
Commercial Building Energy Uses

- Space Cooling
- Cooling Load Driven by Lighting (42% of Cooling Load)
- Lighting
- Heating Assistance from Lighting (23% of Space Heating Load)
- Space Heating
- Refrigeration
- Water Heating
- Ventilation
- Electronics
- Cooking
- Other
- Adjust to SEDS

Source: 2006 Buildings Energy Data Book
Commercial Building Energy Uses

- Space Cooling: Cooling Load Driven by Lighting (42% of Cooling Load)
- Space Heating: Heating Assistance from Lighting (23% of Space Heating Load)
- Lighting
- Refrigeration
- Water Heating
- Ventilation
- Electronics
- Cooking
- Other

Source: 2006 Buildings Energy Data Book
Lighting as Share of U.S. Electricity

- Lighting use
  - About 800 Terawatt hours ($10^{12}$) per year
- Electricity Generation
  - 3815 Terawatt hours per year
- Lighting is 21% of all electricity use
Figure 8-4. Source Light Production by Sector & Source

From “U.S. Lighting Market Characterization”, prepared for DOE EERE by Navigant Consulting, 2002
Figure ES-1 Shares of Sectoral Energy Use by Lighting Technology

From “U.S. Lighting Market Characterization”, prepared for DOE EERE by Navigant Consulting, 2002
Industrial
Forces Shaping Energy Use

• Industrial Sector
  • Inputs required to produce output
    • Level of Economic Output
    • Nature of Production Process
  • Substitution Among Inputs
    • Investment Criteria (interest rates)
    • Price sensitive
Transportation
Forces Shaping Energy Use

• Transport Sector
  • Chosen Level of Mobility
    • Income and Free-time Dependant
    • Urban/Suburban/rural land use patterns
  • Modes of Transport (personal vehicle, airplane, bus, trains)
    • Value of Time
    • Costs of Alternatives (Influenced by oil price)
    • Availability of Alternatives

• Vehicle Characteristics
  • Performance
  • Size
  • Engine, Drive Train Technologies
  • Choices influenced by oil price
Estimated Cost-Minimizing MPG vs. Current Passenger Cars: NRC CAFE Study
Estimated Cost-Minimizing MPG vs. Current “Trucks”: NRC CAFE Study

[Bar chart showing cost effective MPG vs base MPG for different truck classes: SUV-Small, SUV-Mid, SUV-Large, MiniVan, Pick-up Large. Labels for 3-Year and 14-Year Externalities are shown.]