

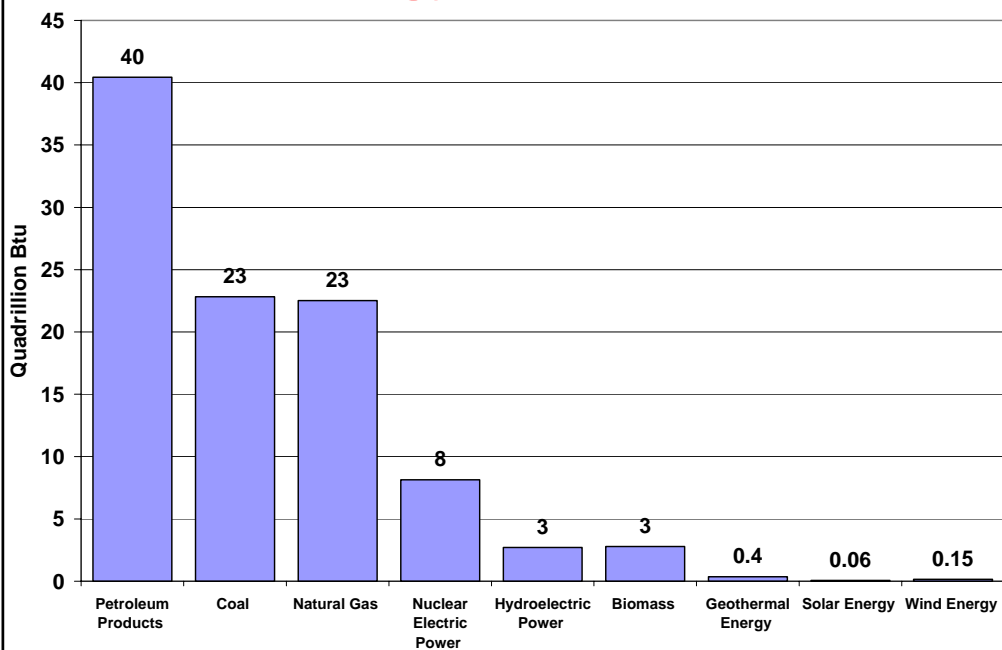
Economic Issues of Energy Efficiency

**Critical Issues in Energy
Federal Reserve Bank of Dallas
November 2, 2006**

**James Sweeney
Stanford University
Director, Precourt Institute for Energy Efficiency
Professor, Department of Management Science and
Engineering**

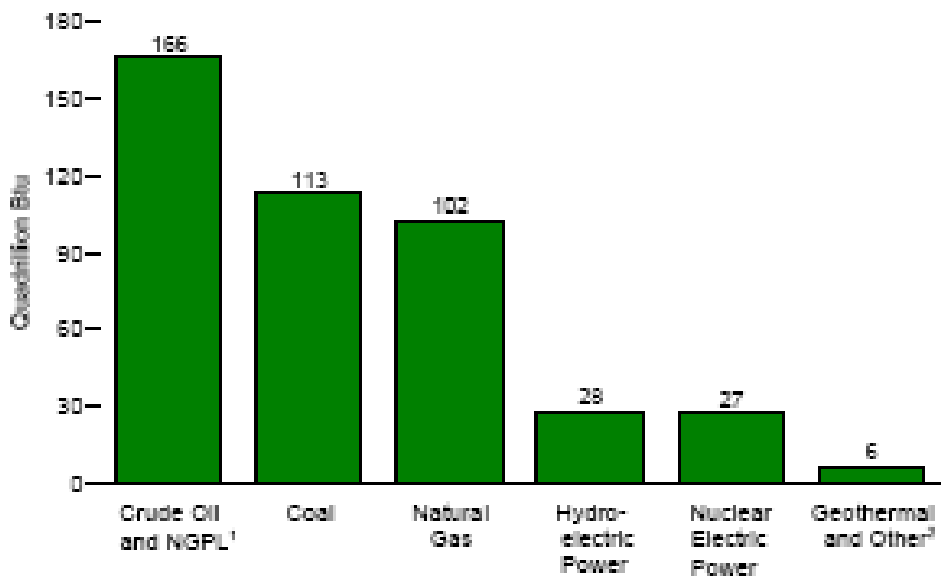
Some Data on Energy Use Patterns

U.S. Energy Supplies: 2005

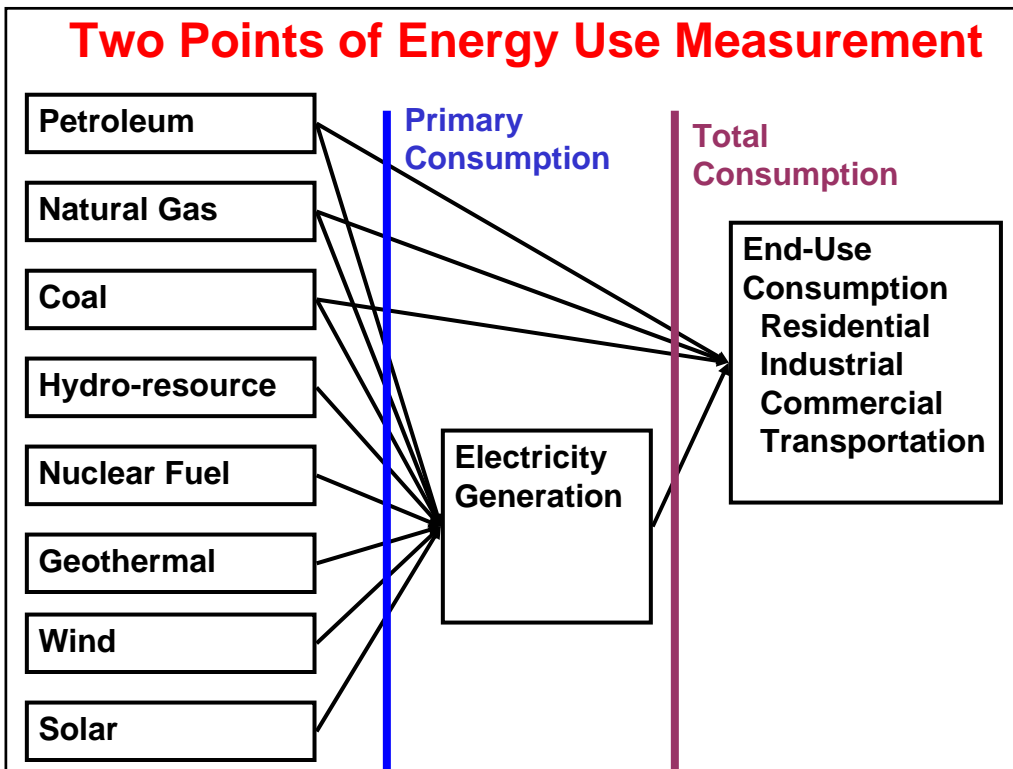
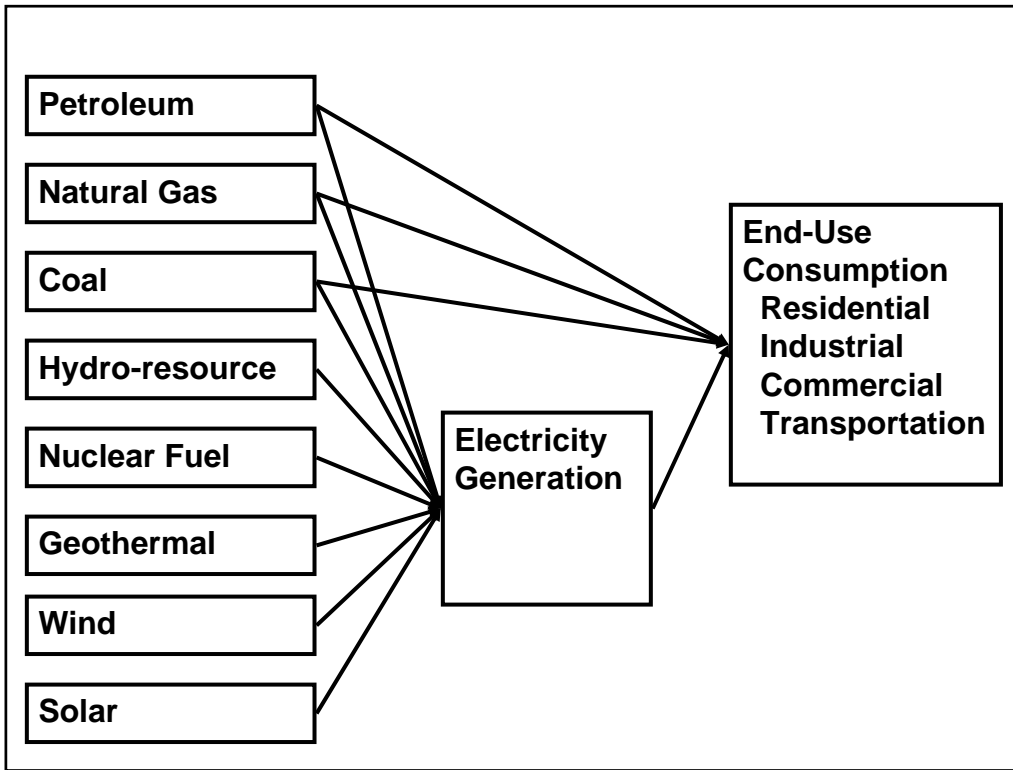


Source: EIA, Annual Energy Review

World Energy Production and Use: 2004 (About 440 Quad Total)



Source: EIA, Annual Energy Review



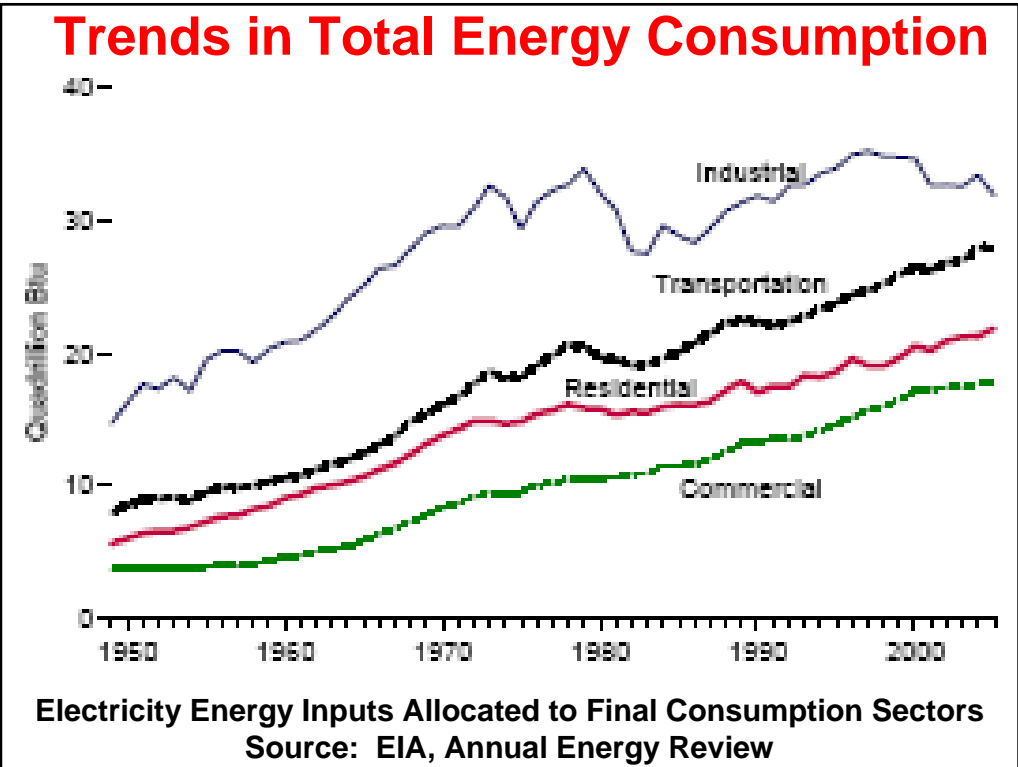
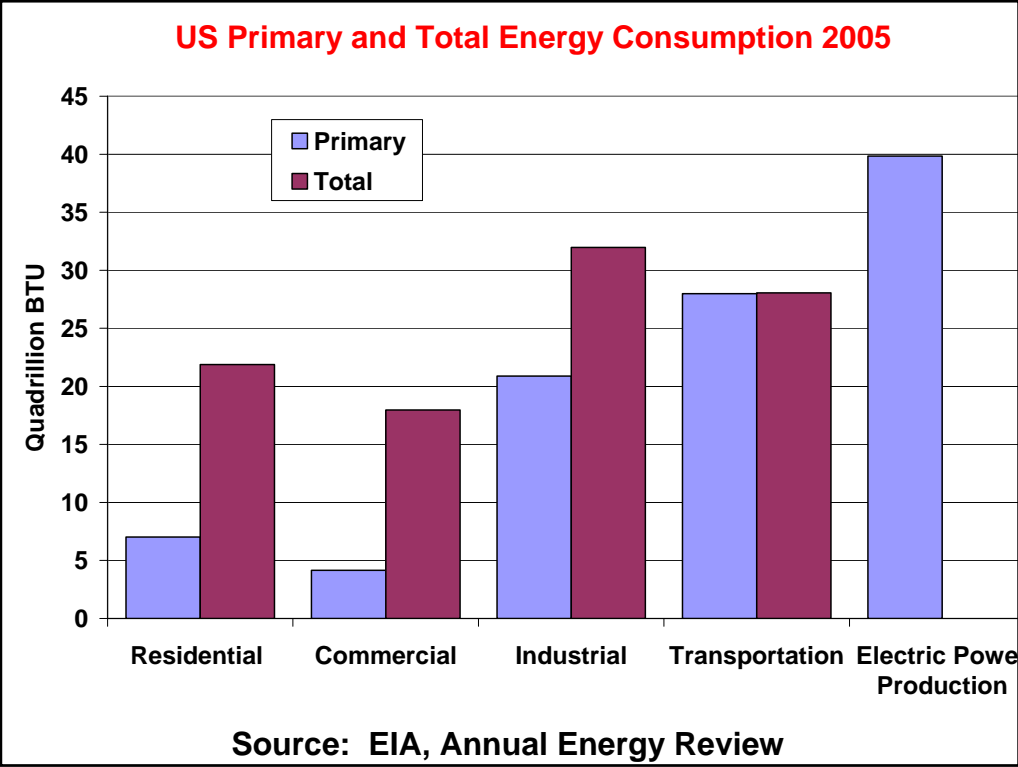
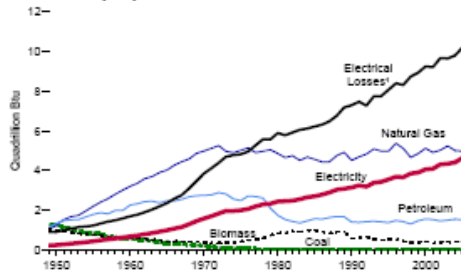
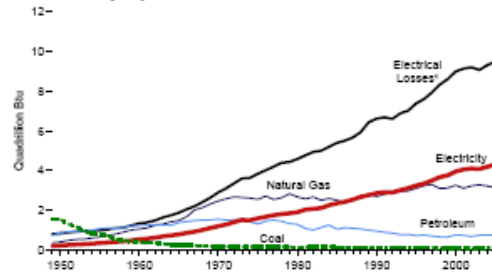


Figure 2.1b Energy Consumption by End-Use Sector, 1949-2005

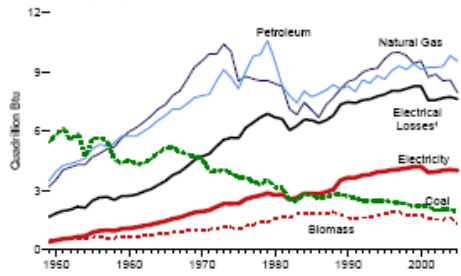
Residential, By Major Source



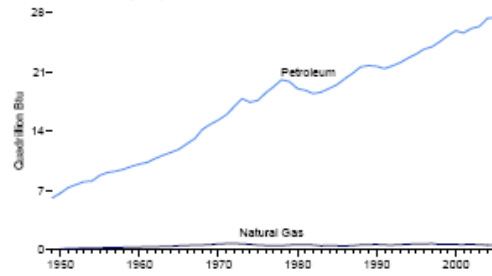
Commercial, By Major Source



Industrial, By Major Source



Transportation, By Major Source



¹ Electrical system energy losses associated with the generation, transmission, and distribution of energy in the form of electricity.

Note: Because vertical scales differ, graphs should not be compared. Sources: Tables 2.1b-2.1e.

Analyzing Energy Demand

Some Basic Physical Realities

- **No energy is created or destroyed (except in nuclear reactions)**
- **Energy can be converted among various forms (mechanical, chemical, thermal, electrical, radiant)**
- **Conversion processes can be complex or simple**
- **Conversion is never 100% efficient**
- **Energy comes from the physical environment and ultimately is released back into the physical environment.**

Energy as a Derived Demand

- **Demand for energy is derived from desires to obtain desired services.**
- **Not derived from preferences for the energy commodity itself.**
- **Energy demand depends primarily on demand for desired services, availability and properties of energy conversion technologies, costs of energy, technologies used for conversion, and information about options.**

Demand Substitution Among Energy Commodities

- **Some energy services can be provided by several different energy commodities.**
 - **Homes could be heated using electricity, natural gas, oil, or wood. Each can be converted to thermal energy.**
 - **Energy commodities are typically economic substitutes for one another.**
- **Substitutability is made possible and is limited by available energy conversion technologies.**
- **Usually various energy commodities are imperfect substitutes**
 - **Much greater substitutability in the long run than in the short run.**
- **Degree of substitutability can be sharply altered by development of new conversion alternatives.**

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**
- **Commercial Sector**
 - **Building Characteristics**
 - **Size**
 - **Lighting, heating, cooling technologies**
 - **Energy Management**
 - **Light Controls**
 - **Heating/Cooling over time**

Forces Shaping Energy Use

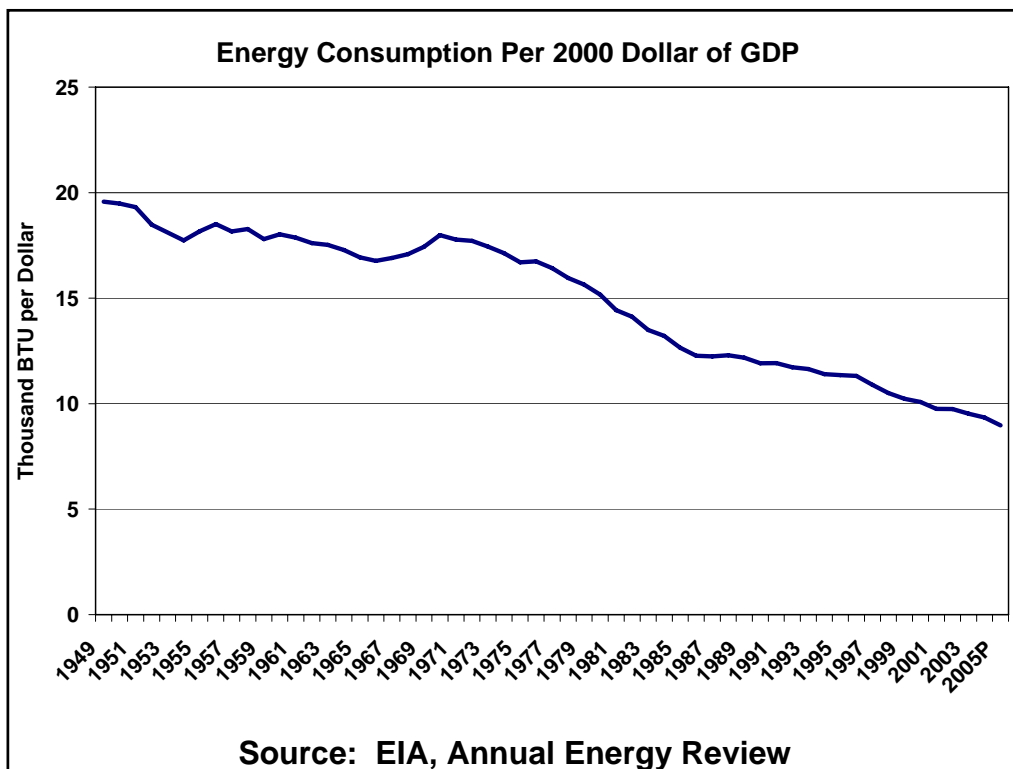
- **Residential Sector**
 - **Building Characteristics**
 - Size
 - Lighting, heating, cooling technologies
 - Insulation
 - **Energy Management**
 - Thermostat settings
 - Lighting levels chosen
 - **Plug power**
 - Appliance saturation
 - Vintage of Refrigeration

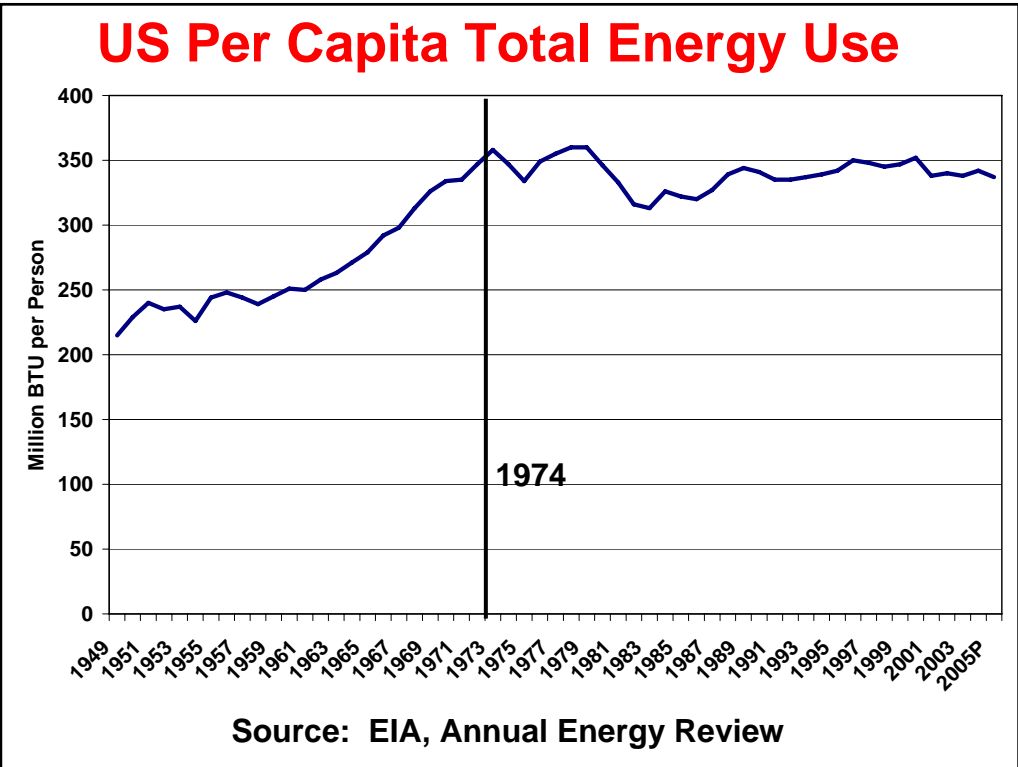
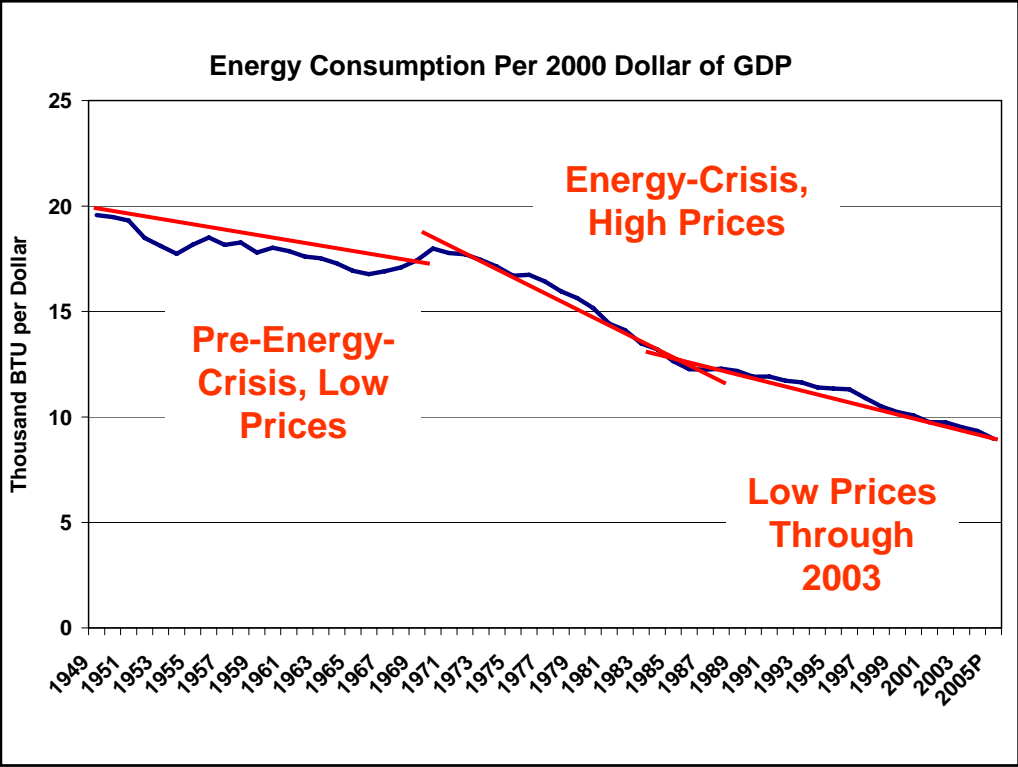
Forces Shaping Energy Use

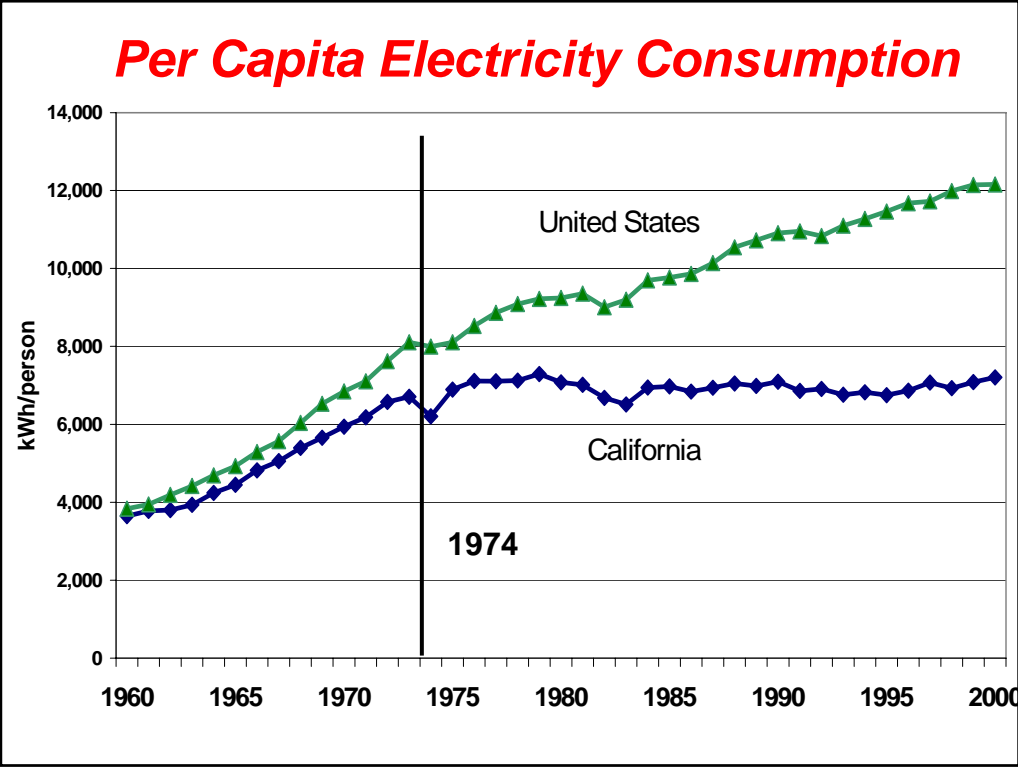
- **Transport Sector**
 - **Chosen Level of Mobility**
 - Income and Free-time Dependant
 - Urban/Suburban/rural land use patterns
 - **Modes of Transport (personal vehicle, airplane, bus, trains)**
 - Value of Time
 - Costs of Alternatives
 - Availability of Alternatives
 - **Vehicle Characteristics**
 - Performance
 - Size
 - Engine, Drive Train Technologies

Forces Shaping Energy Use

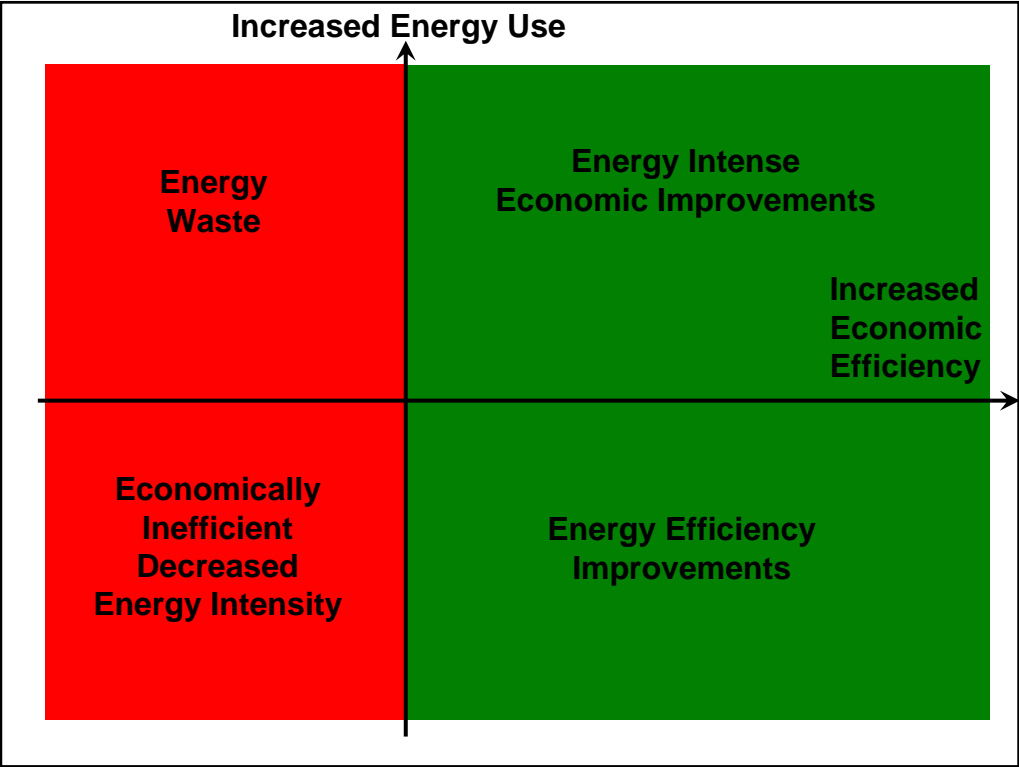
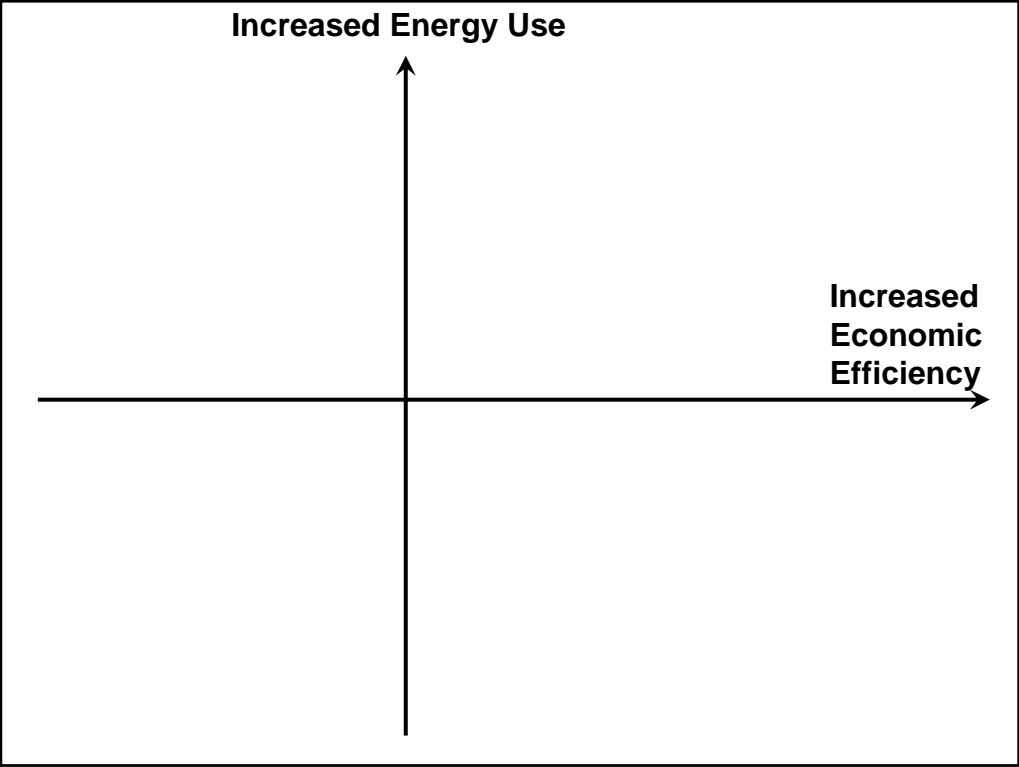
- **Electricity Generation**
 - **Inputs required to produce output**
 - Level of Electricity Output
 - Electricity Generation Process
 - **Substitution Among Inputs**
 - Investment Criteria (interest rates)
 - Price sensitive
 - **Regulatory Rules**
 - Market Structure
 - Renewable Portfolio Mandates
 - Allowable Rate of Return
 - Carbon Dioxide Constraints

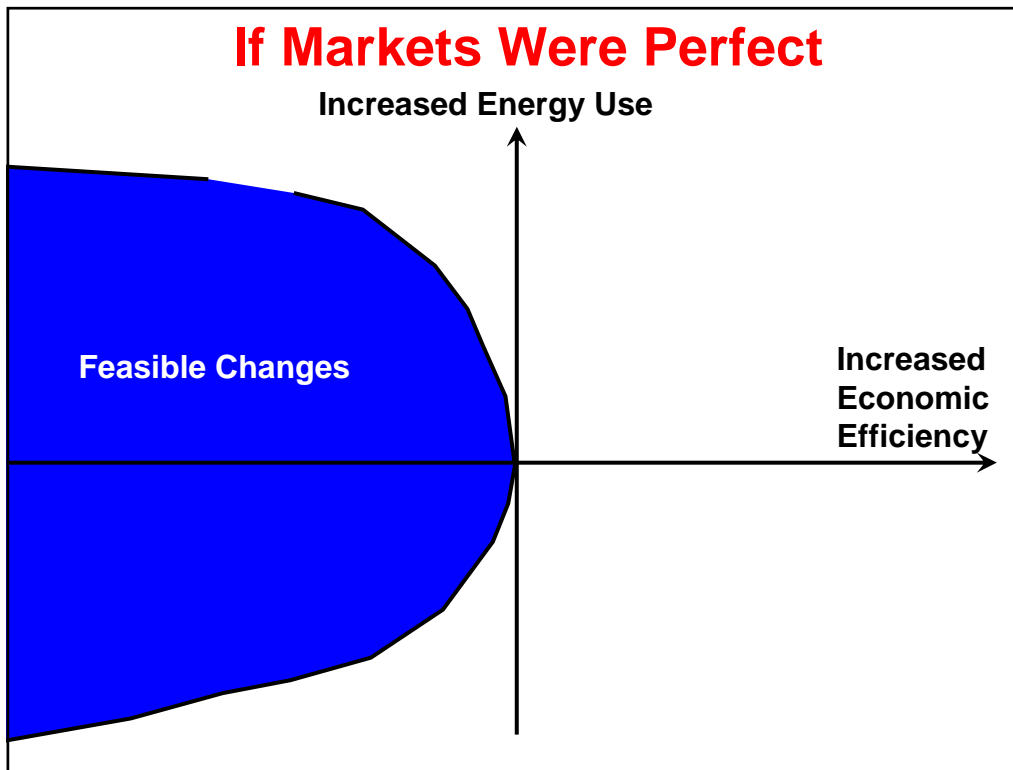






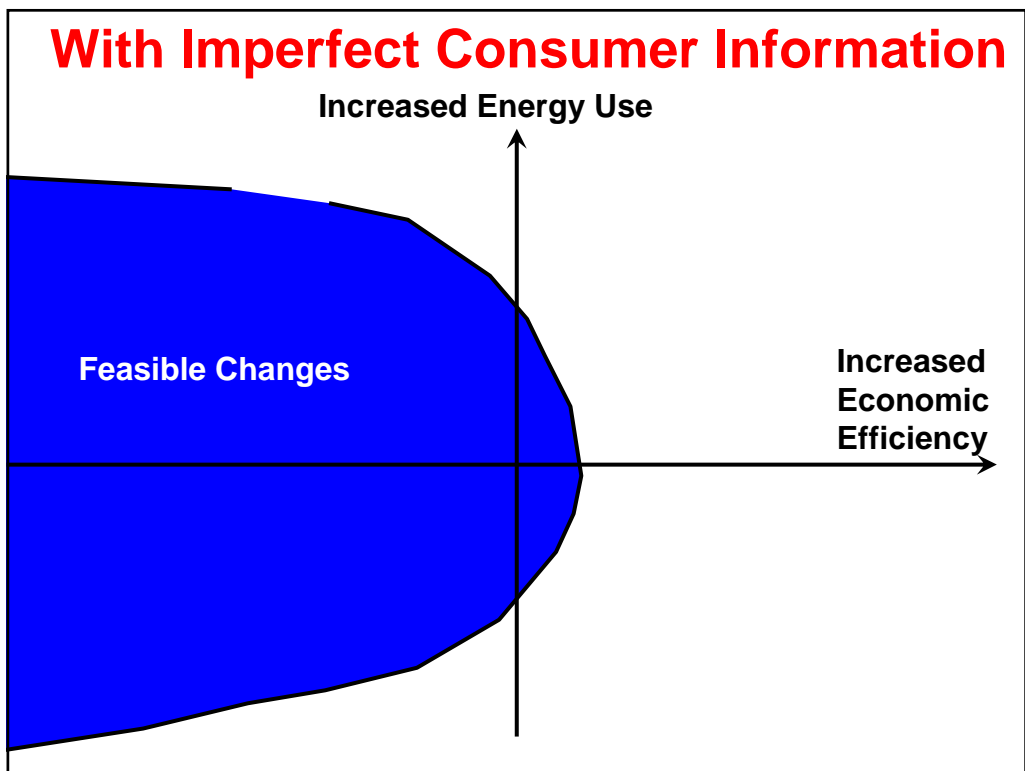
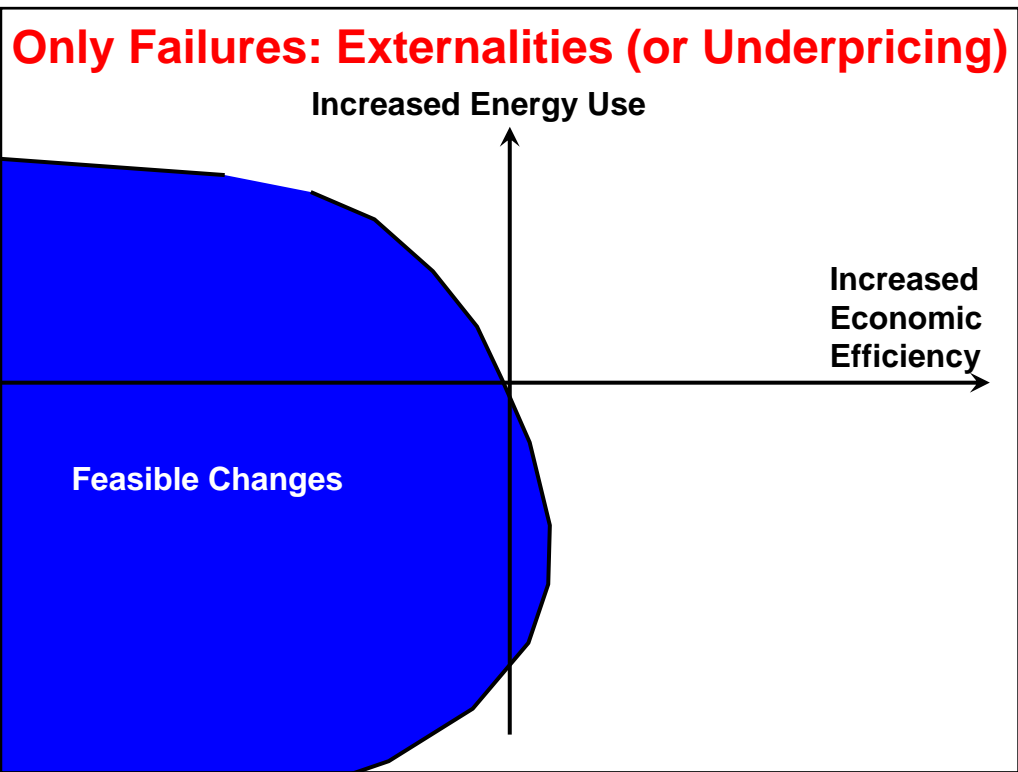
**Energy Efficiency:
Economically Efficient Reductions in
Energy Use Intensity**



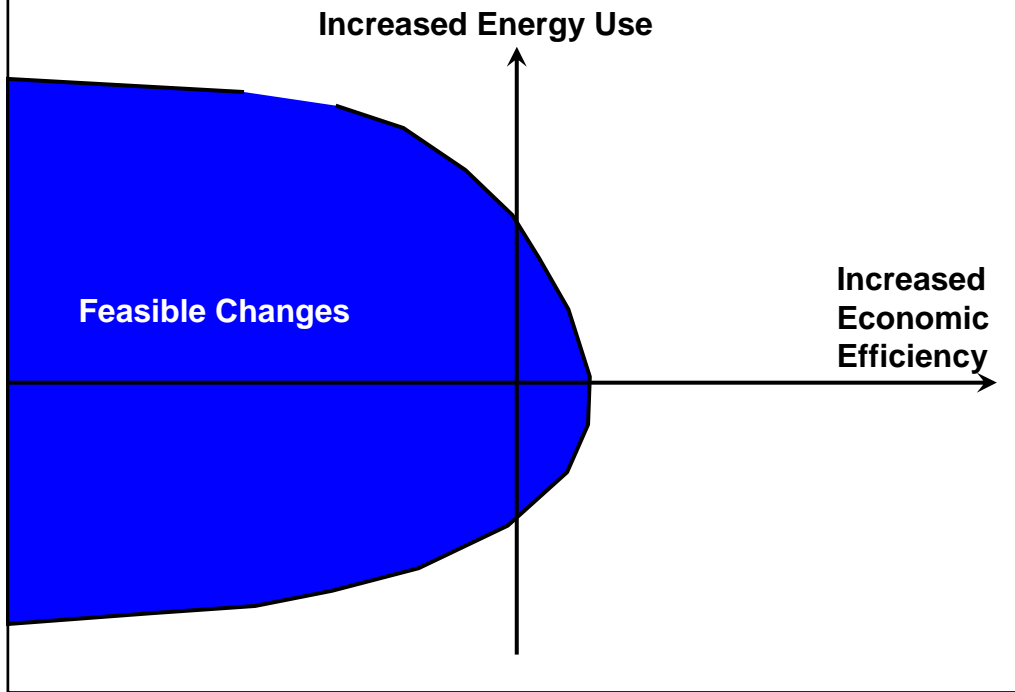


Some Sources of Efficiency Failures

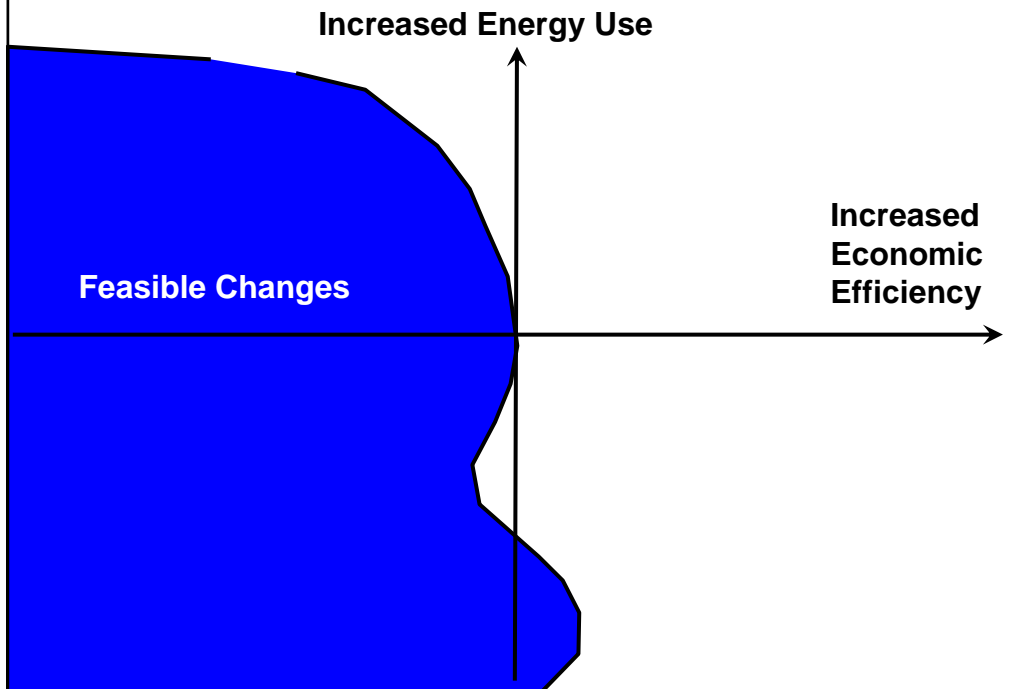
- **Externalities of Energy Use**
 - Global Climate Change
 - Risks of Energy Price Shocks
 - Limitations on our Foreign Policy Options
 - Terms of Trade Impacts (Pecuniary “Externalities”)
- **Pricing Below Marginal Cost**
 - Non-time-differentiated Electricity Pricing
- **Information Asymmetry**
 - Consumer Product Marketing
 - New Building Construction
- **Incomplete Technology Options**
 - Under-investment
 - Sub-optimal technology directions, due to externalities
- **Non-Convexities**
 - Learning By Doing Technology Spillovers
 - “Chicken and Egg” Problems

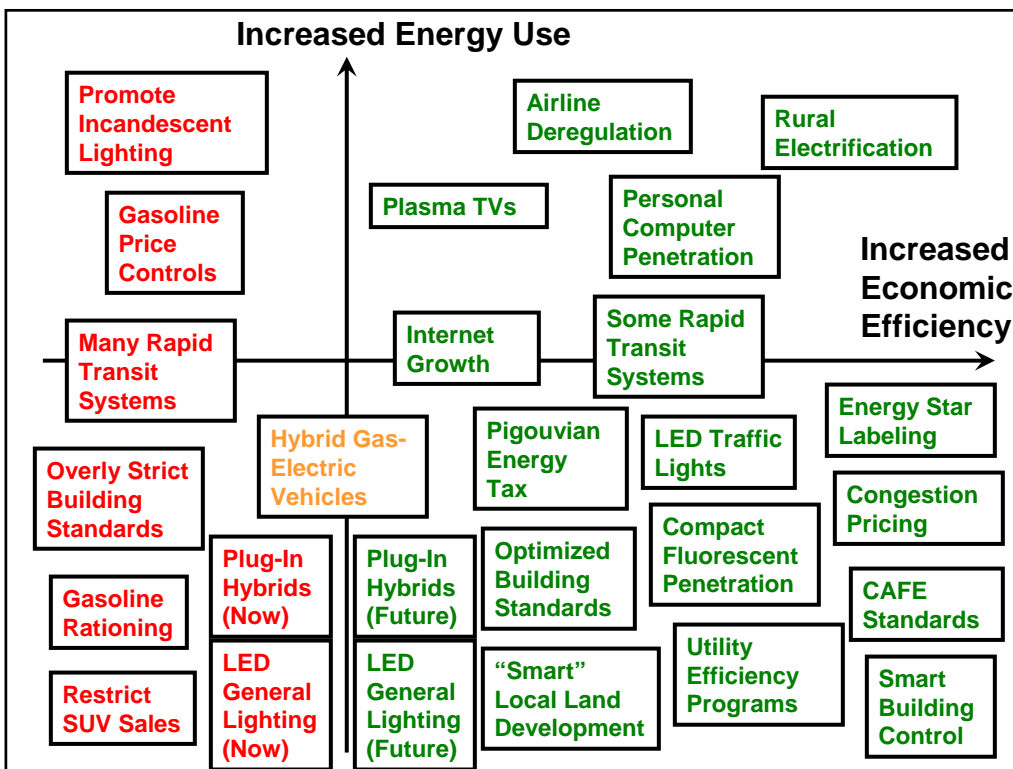
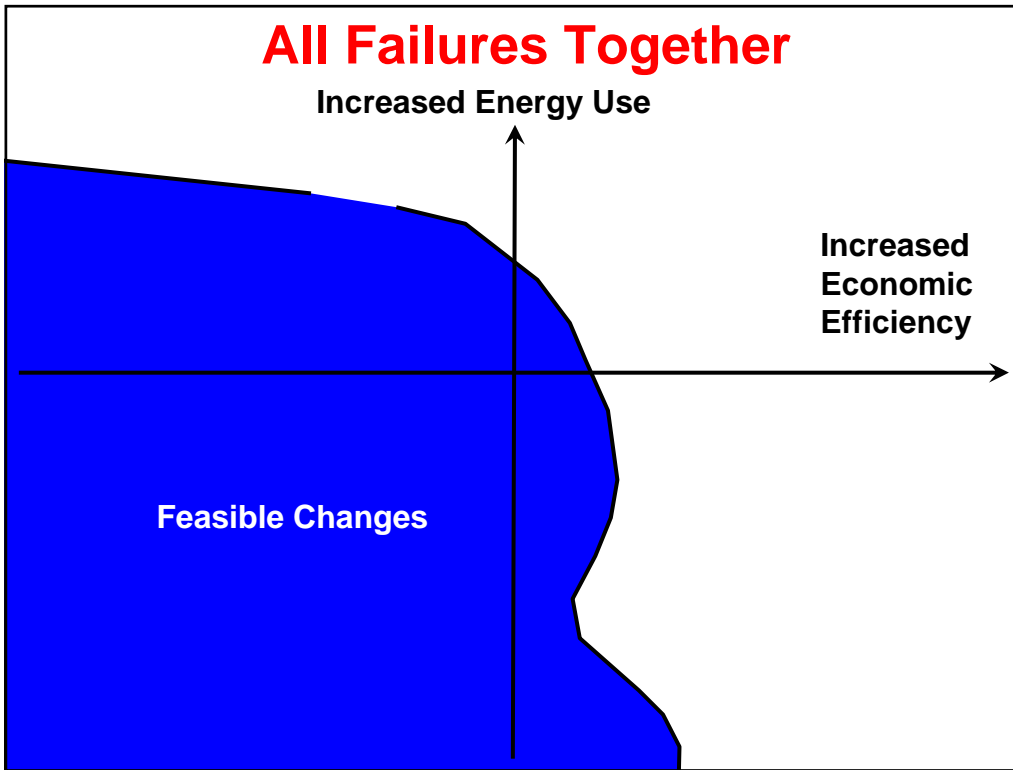


Incomplete Technology Options



Non-Convexities Only





Trends in Refrigeration Energy Use

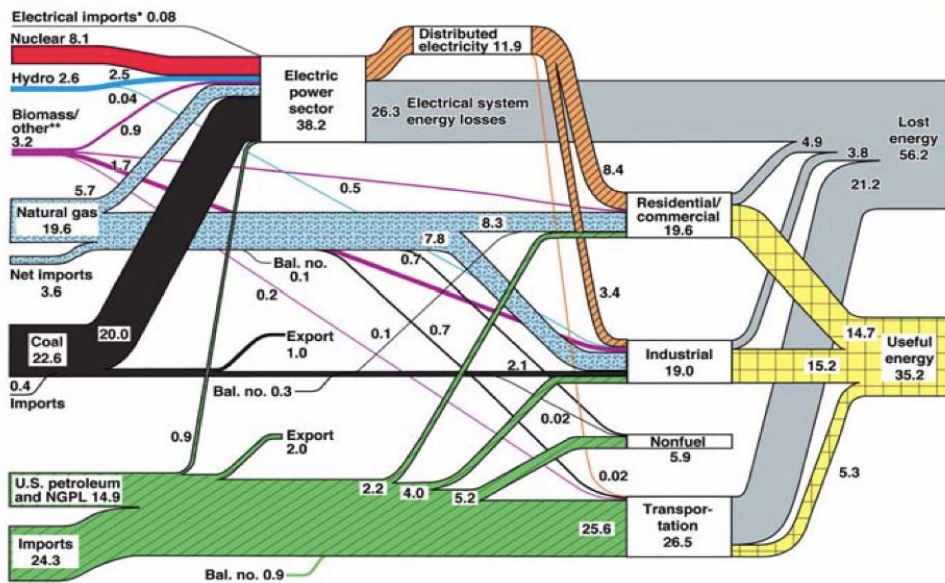


FIGURE E-1 Electricity consumed by refrigerators, 1947 to 2001. SOURCE: Goldstein and Geller, 1998.

Energy Flows: (Thanks to Gene Berry)

U.S. Energy Flow Trends – 2002

Net Primary Resource Consumption ~97 Quads



Bottom Line

- **Increases of economic efficiency can be accomplished through decreases of energy use – energy efficiency improvements**
 - **In principle, based on understanding of market failures**
 - **In practice, based on observations of options and human choices**
 - **In practice, based on technology and systems innovation**
- **The potential, I believe, is large for improvements in energy efficiency**