

Economic Issues of Energy Efficiency

CEE 320

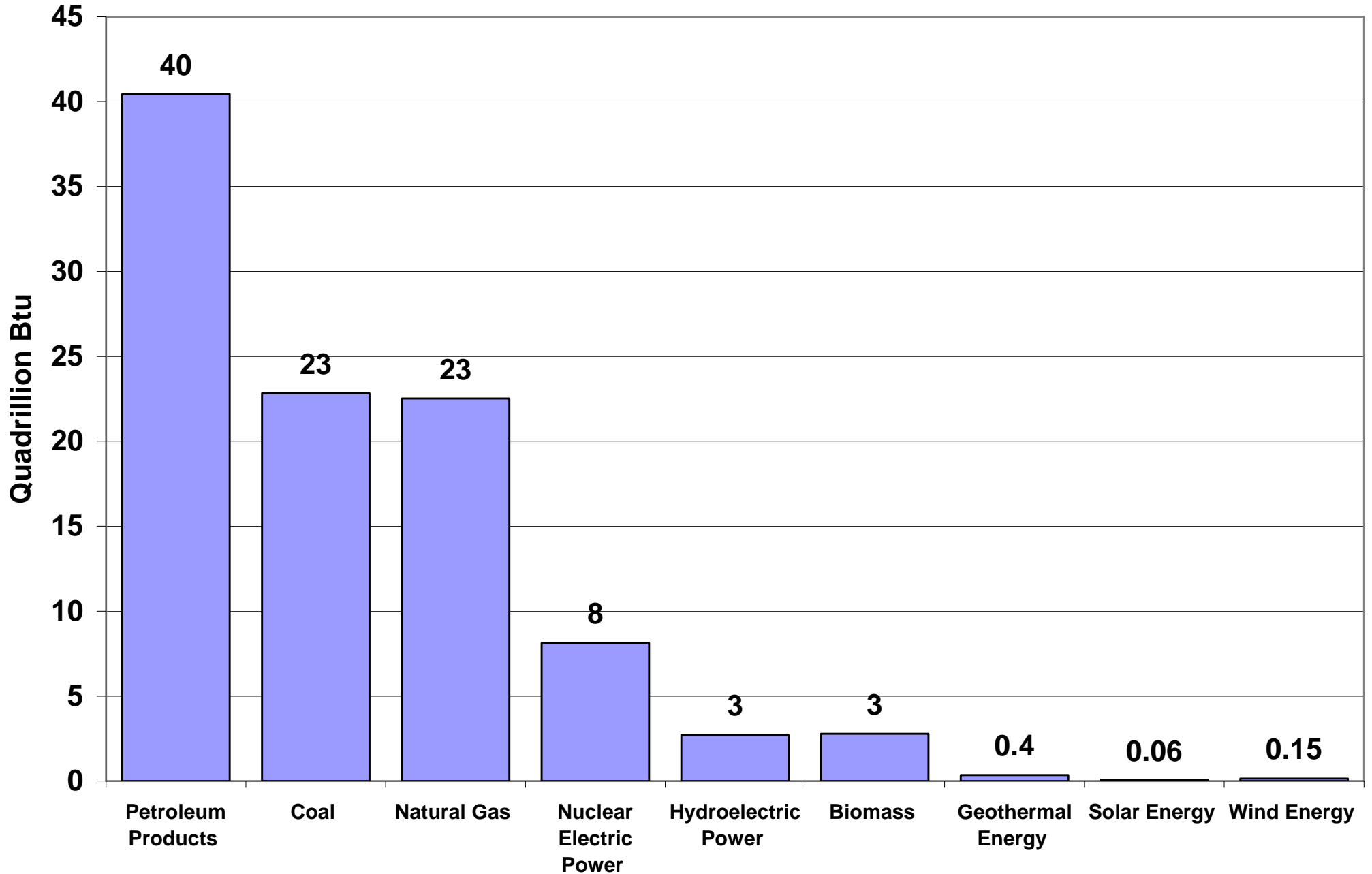
James Sweeney

Stanford University

Director, Precourt Institute for Energy Efficiency

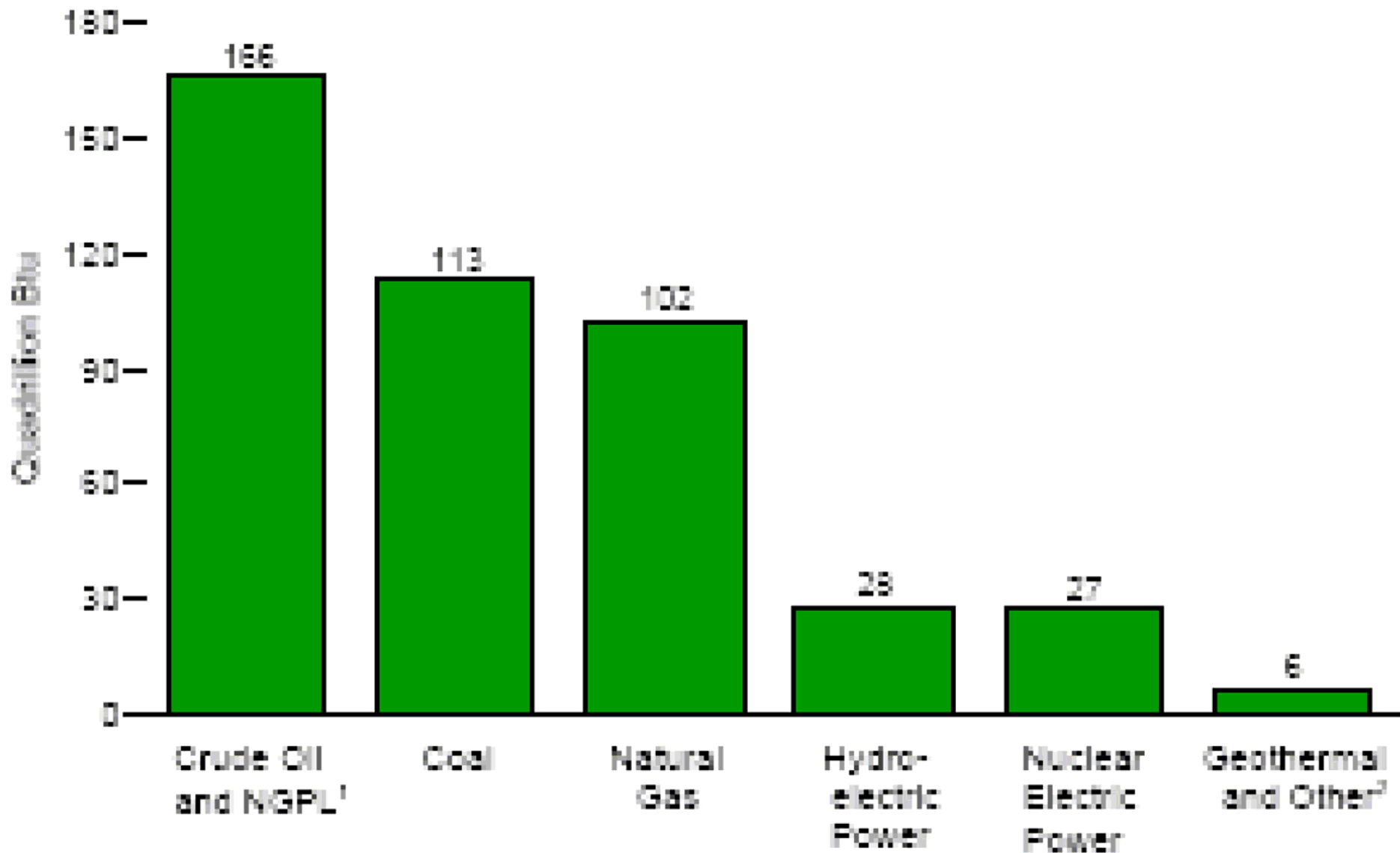
**Professor, Department of Management Science and
Engineering**

U.S. Energy Usage: 2005



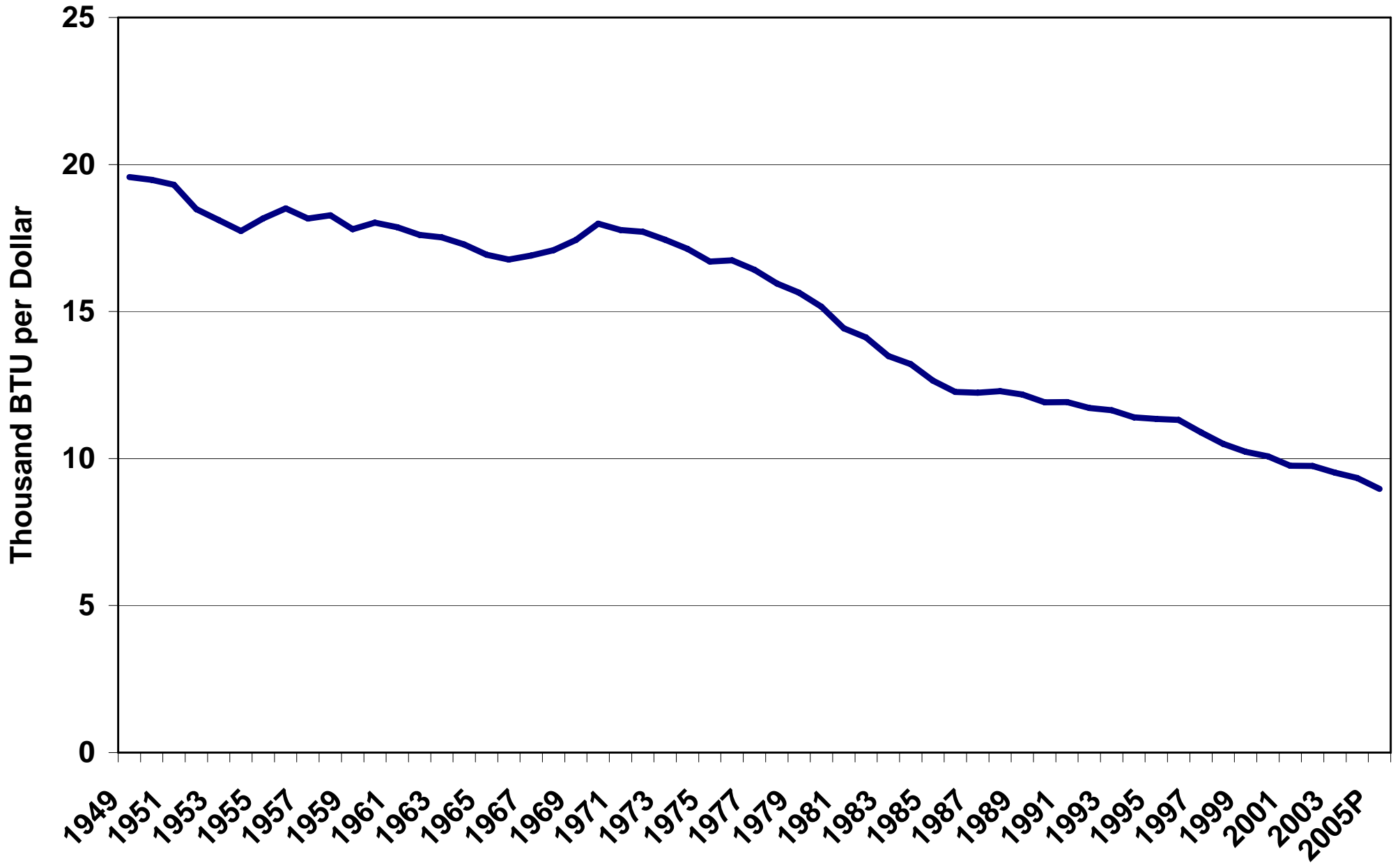
Source: EIA, Annual Energy Review

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



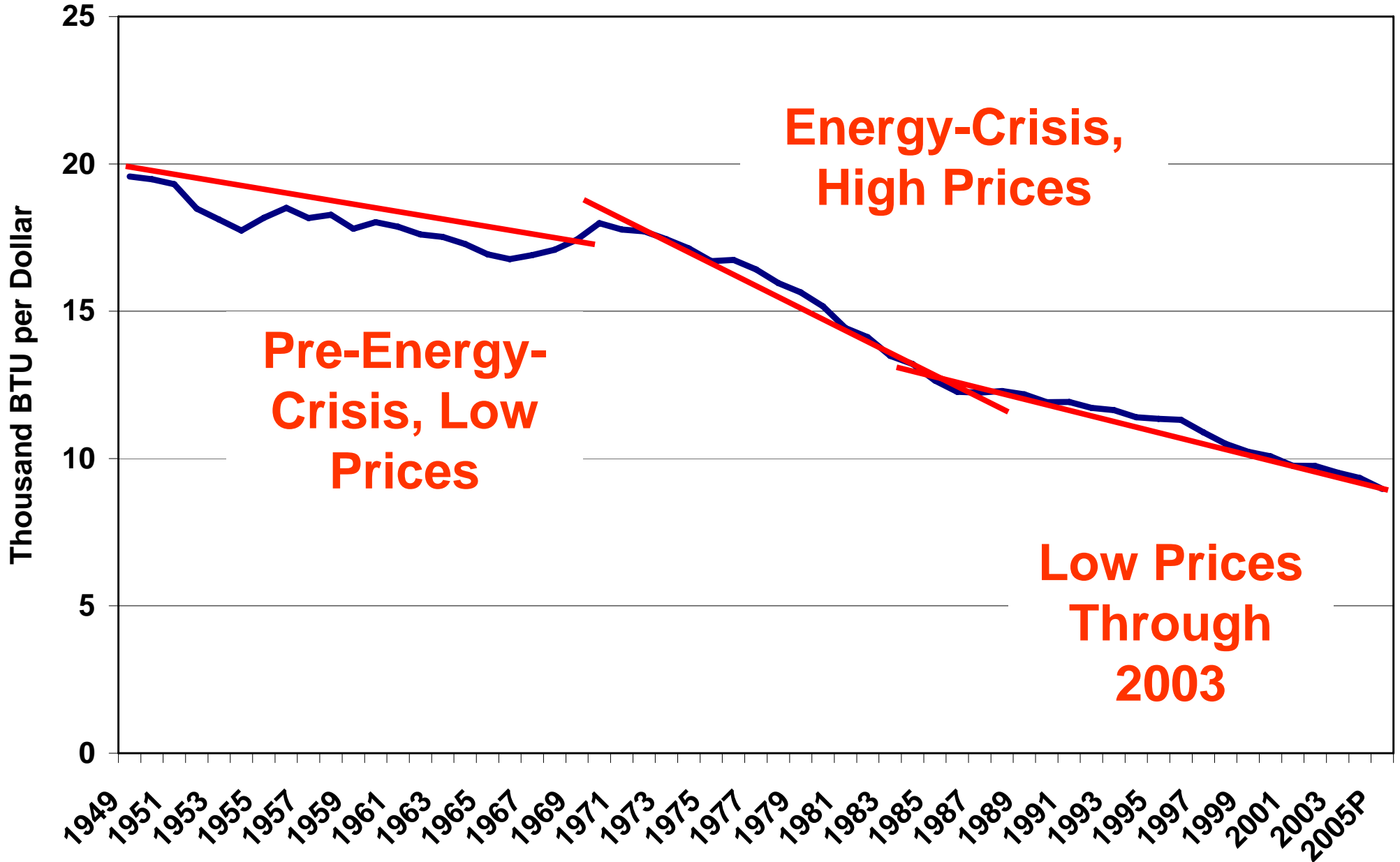
Source: EIA, Annual Energy Review

Energy Consumption Per 2000 Dollar of GDP

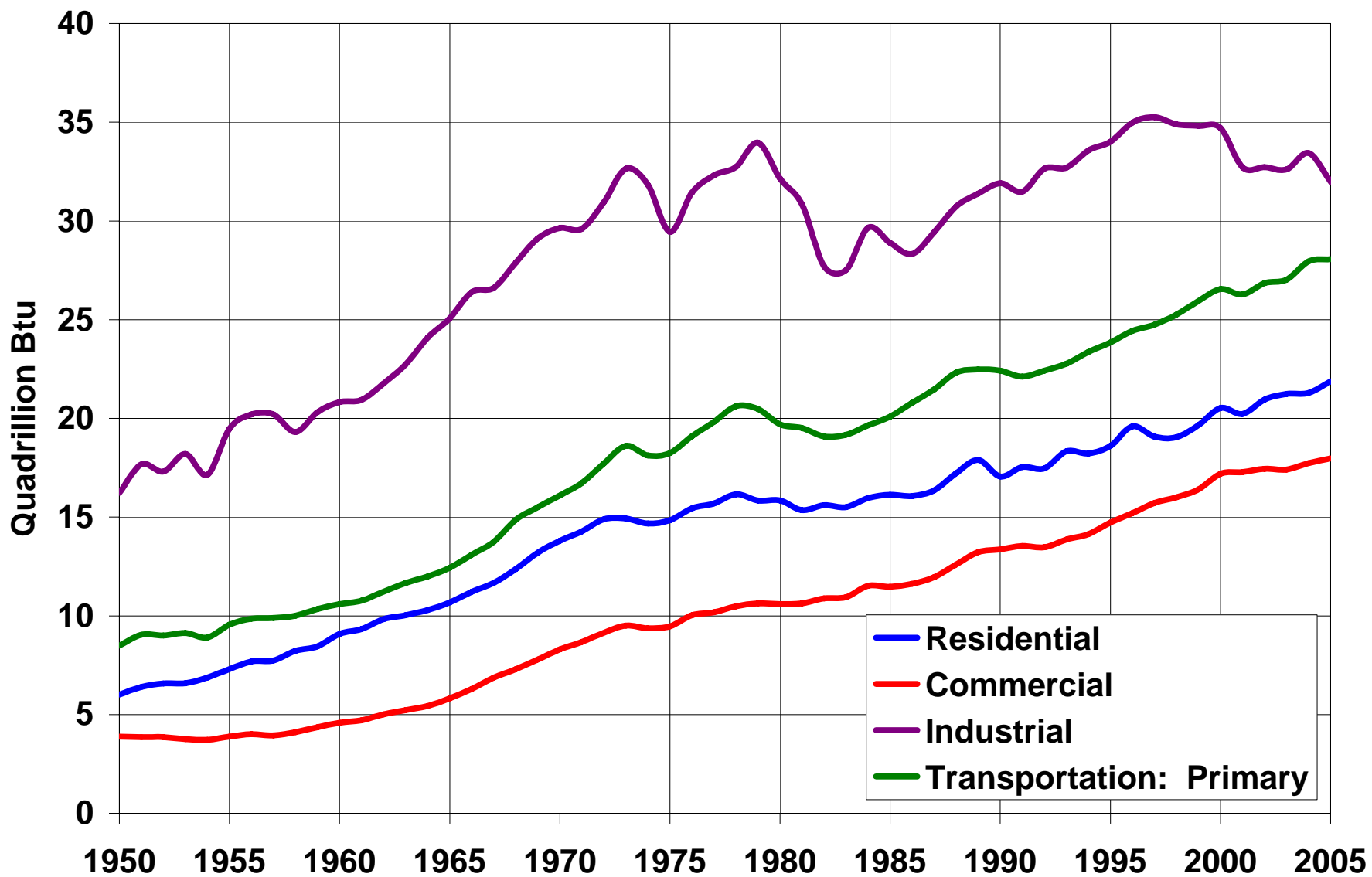


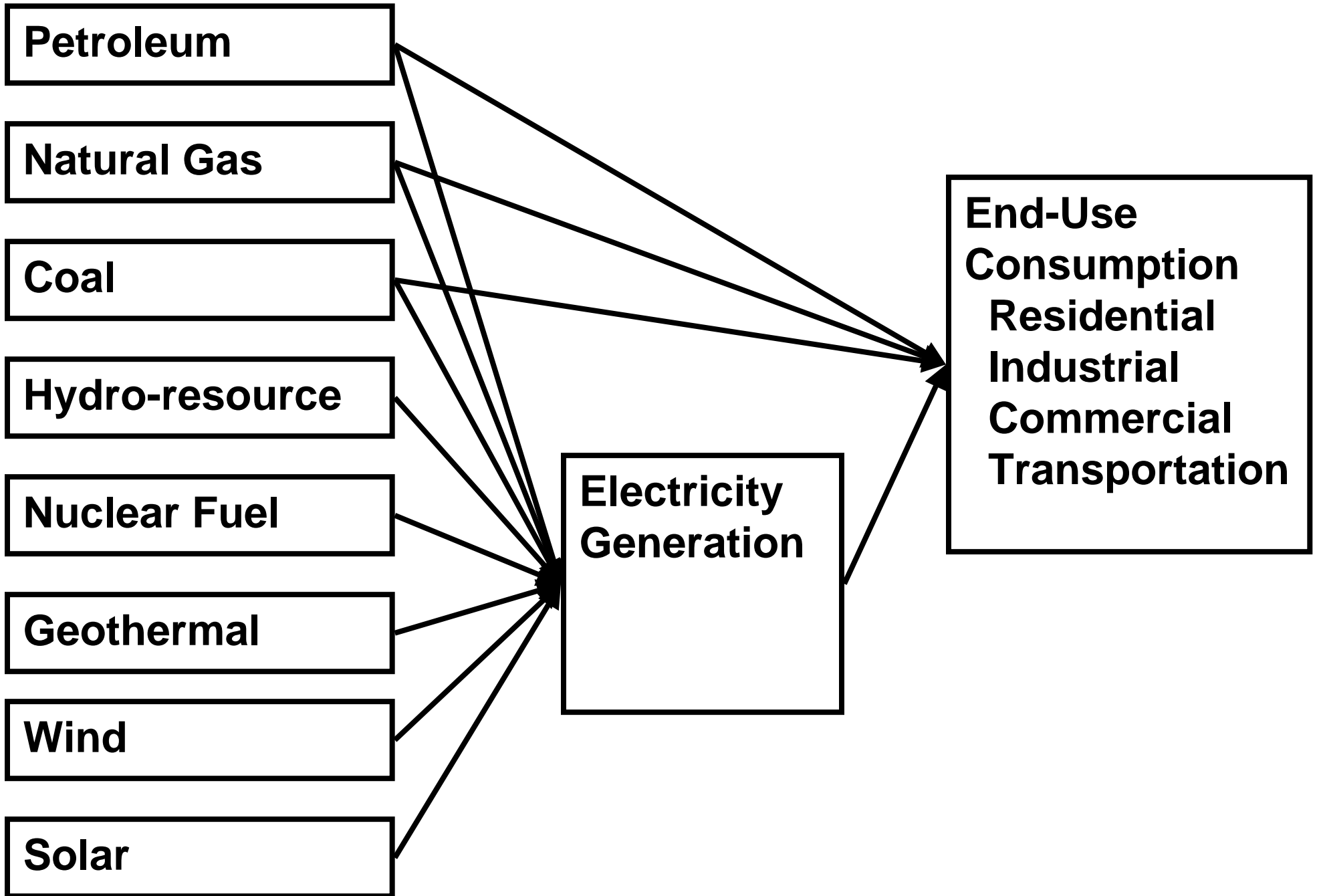
Source: EIA, Annual Energy Review

Energy Consumption Per 2000 Dollar of GDP

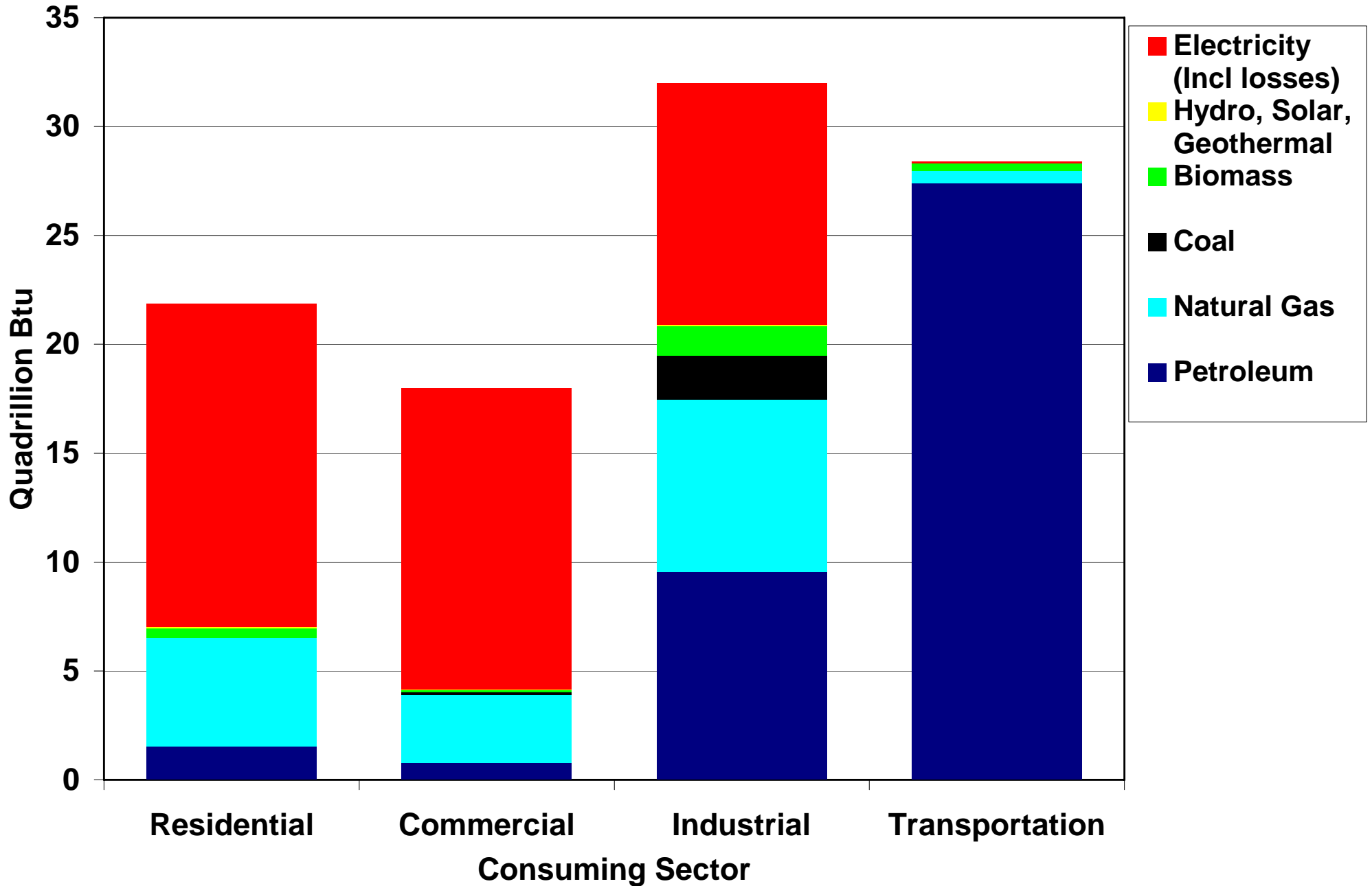


Trends in U.S. Sectoral Energy Use

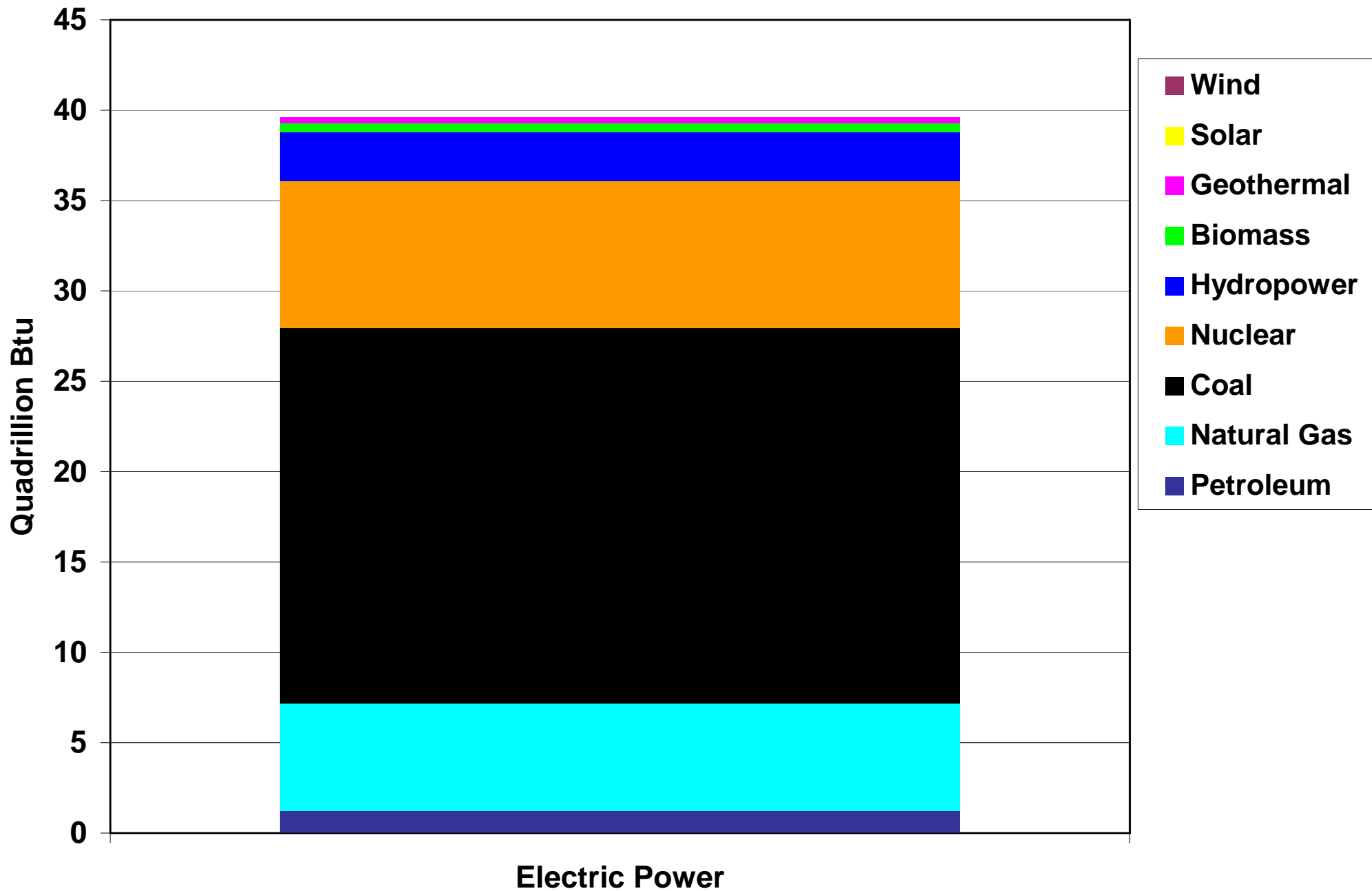




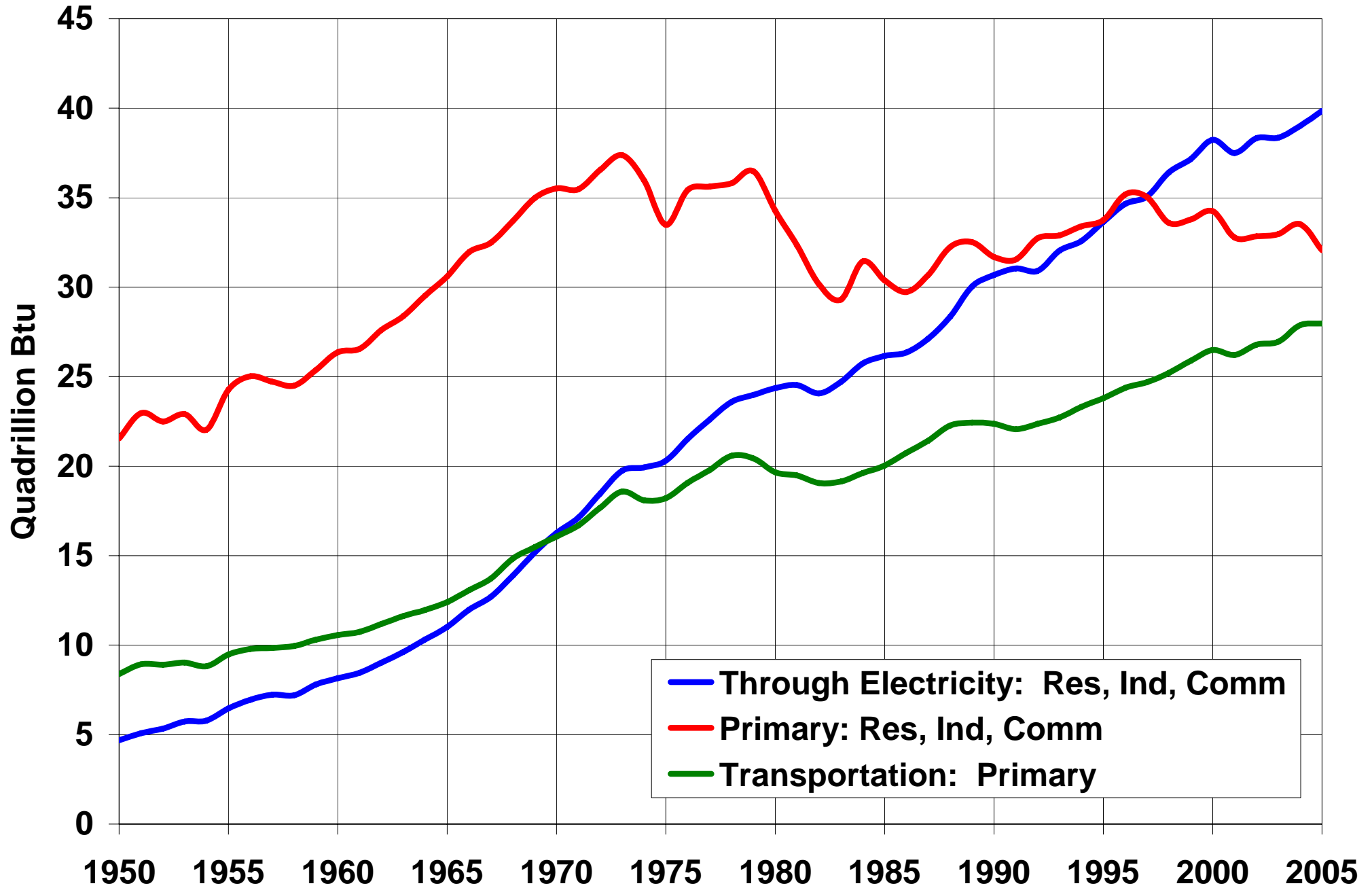
U.S. Sectoral Energy Use: 2005



Primary Energy Use: Electric Generation 2005



US Primary Energy and Electricity Use by Sectors



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:

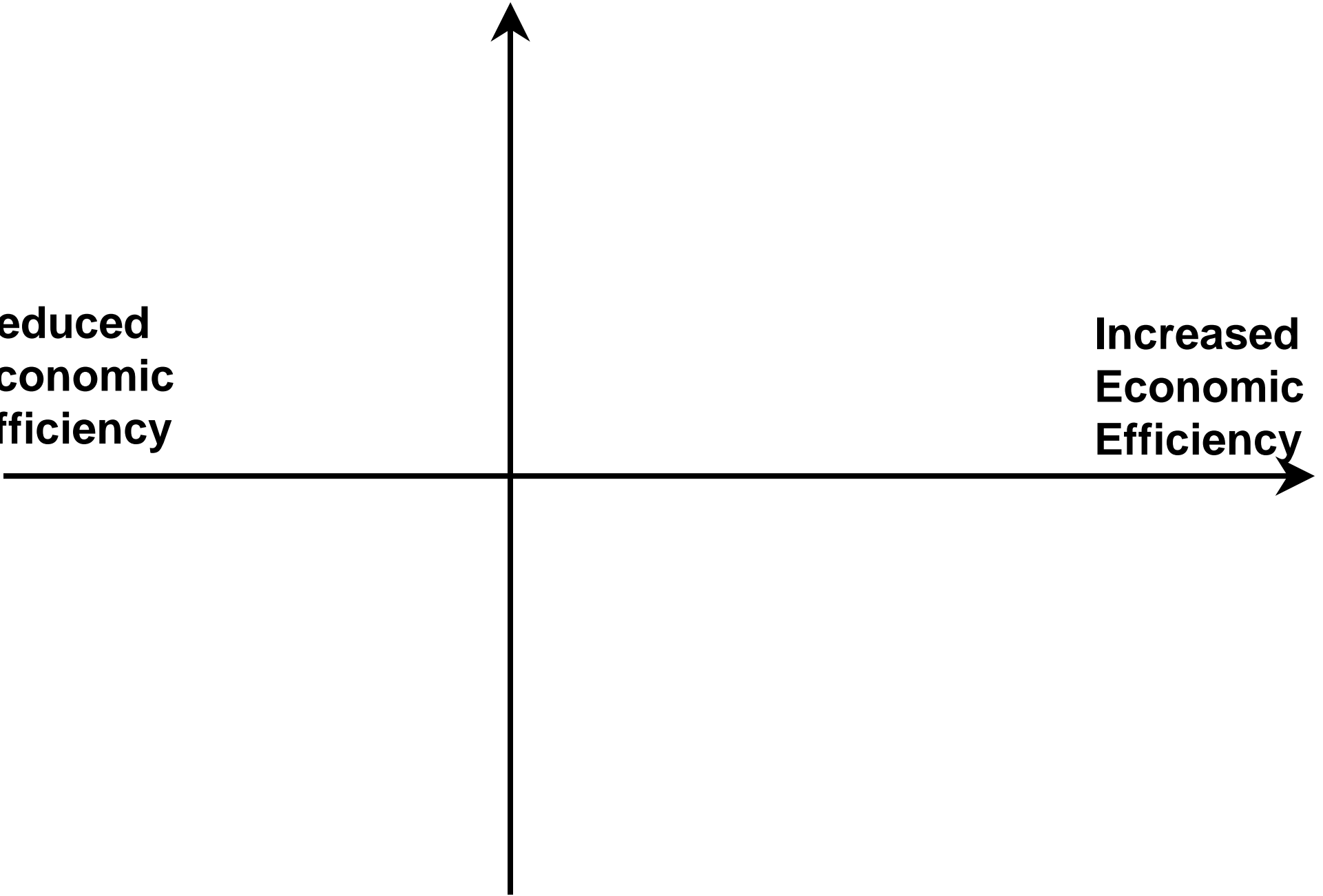
**Economically Efficient Reductions in
Energy Use Intensity**

Decreased Energy Use

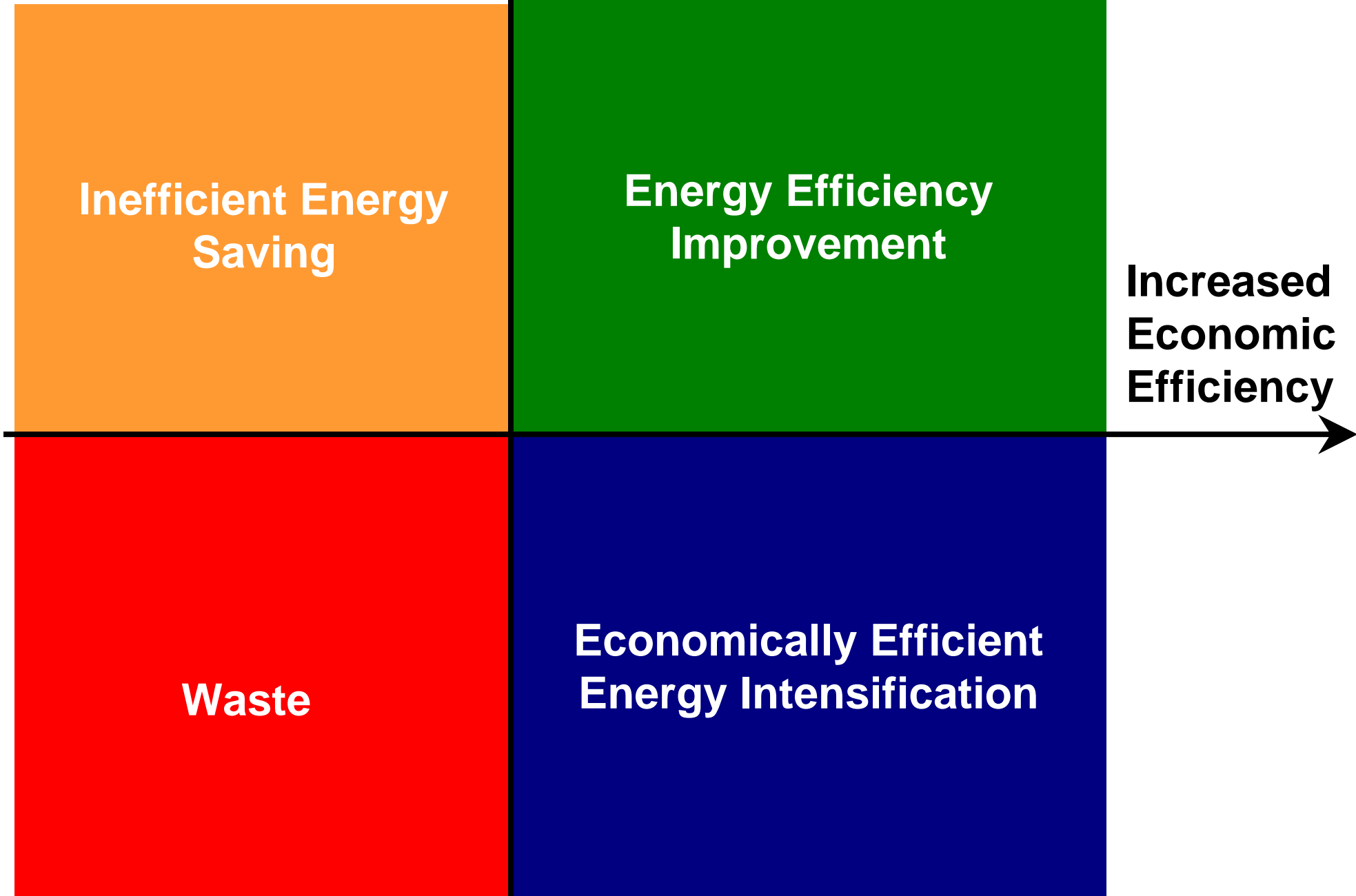
**Reduced
Economic
Efficiency**

**Increased
Economic
Efficiency**

Increased Energy Use



Decreased Energy Use



Inefficient Energy Saving

Energy Efficiency Improvement

Increased Economic Efficiency

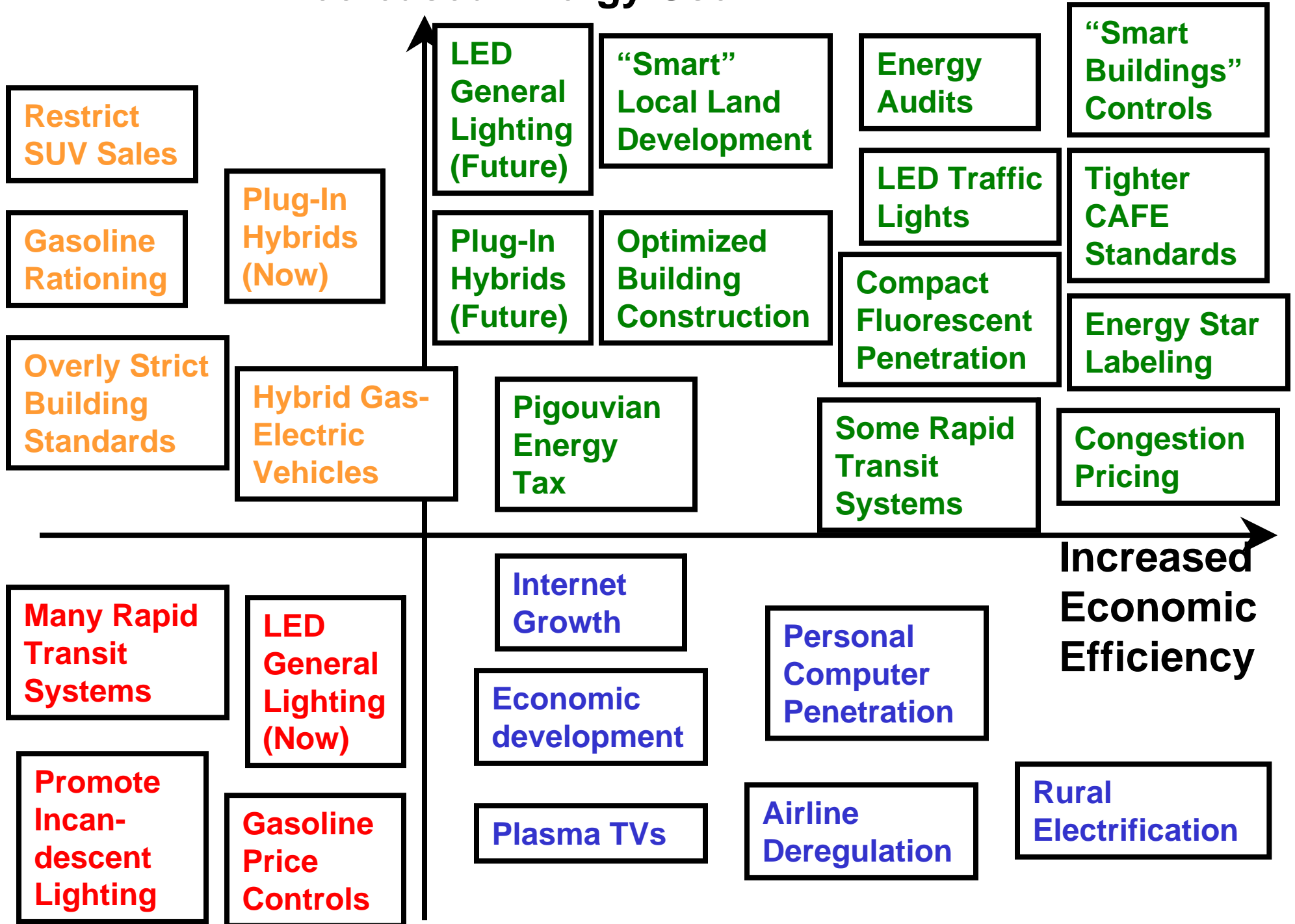
Waste

Economically Efficient Energy Intensification

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



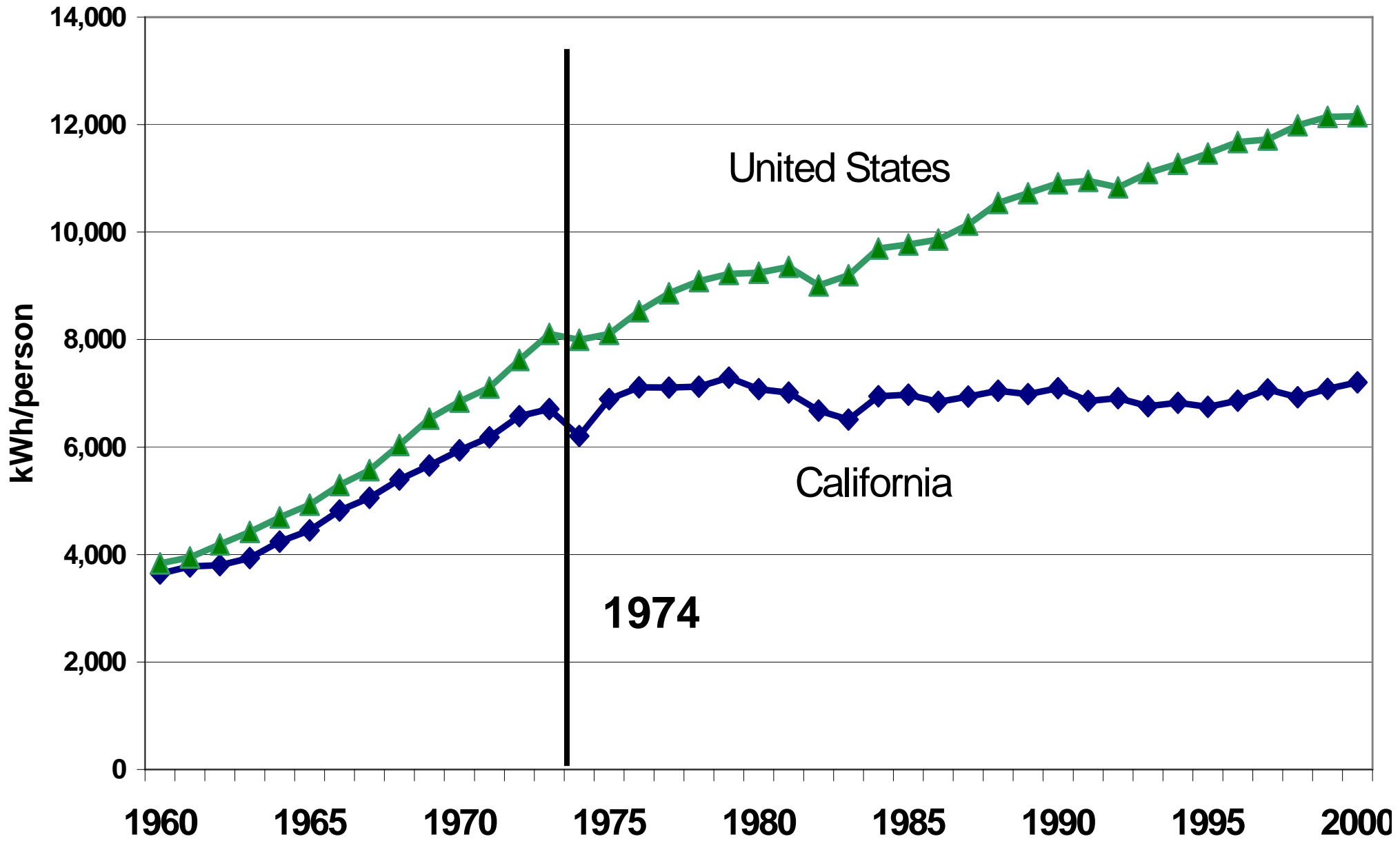
Two Historical Examples

Trends in Refrigeration Energy Use



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

Per Capita Electricity Consumption

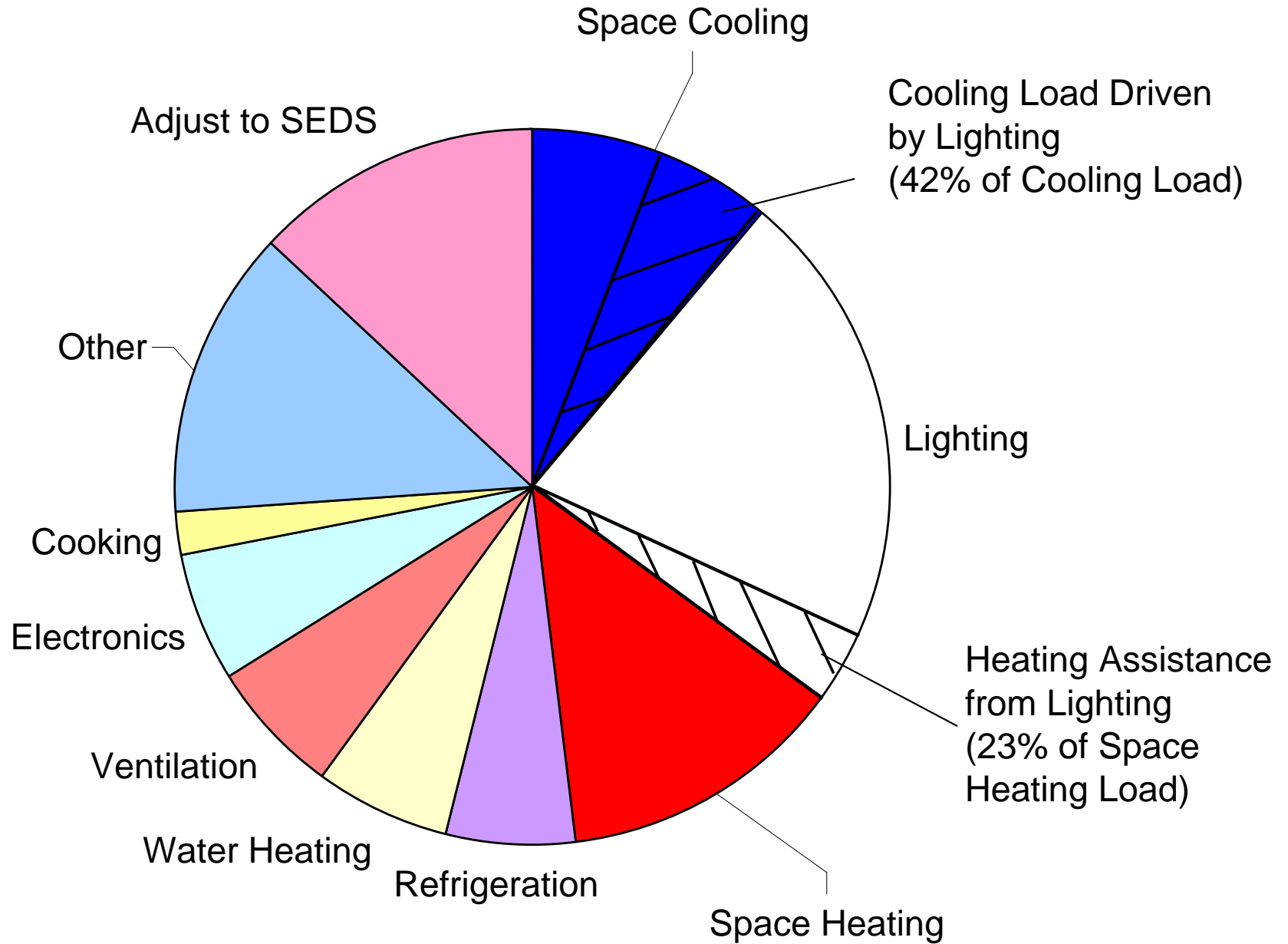


Residential, Commercial

Forces Shaping Energy Use

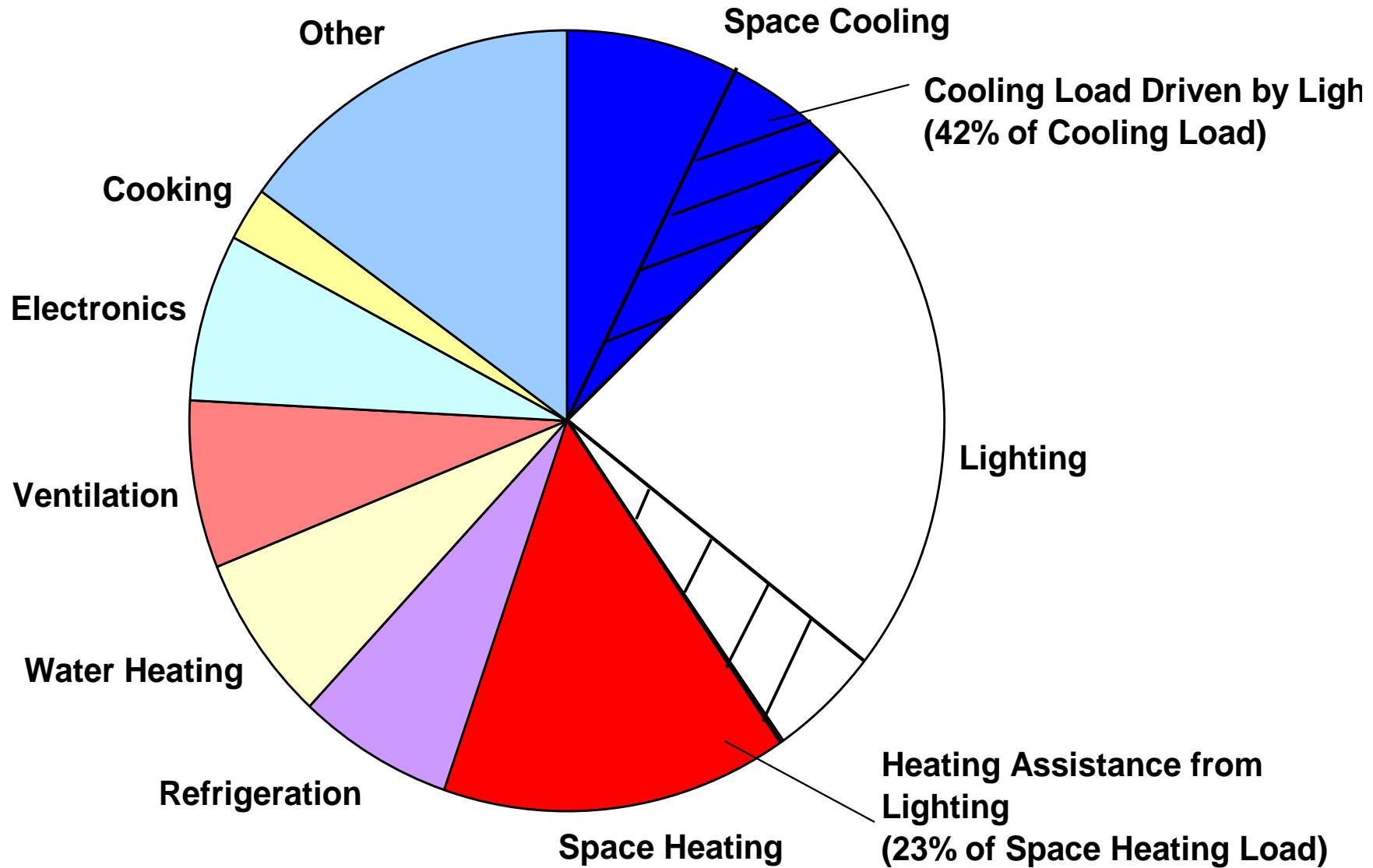
- **Residential and Commercial Sector**
 - **Building Characteristics**
 - Size
 - Lighting, heating, cooling technologies
 - Insulation
 - **Energy Management**
 - Thermostat settings
 - Lighting levels chosen
 - **Plug power**
 - Appliance saturation
 - Vintage of Refrigeration

Commercial Building Energy Uses



Source: 2006 Buildings Energy Data Book

Commercial Building Energy Uses



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**

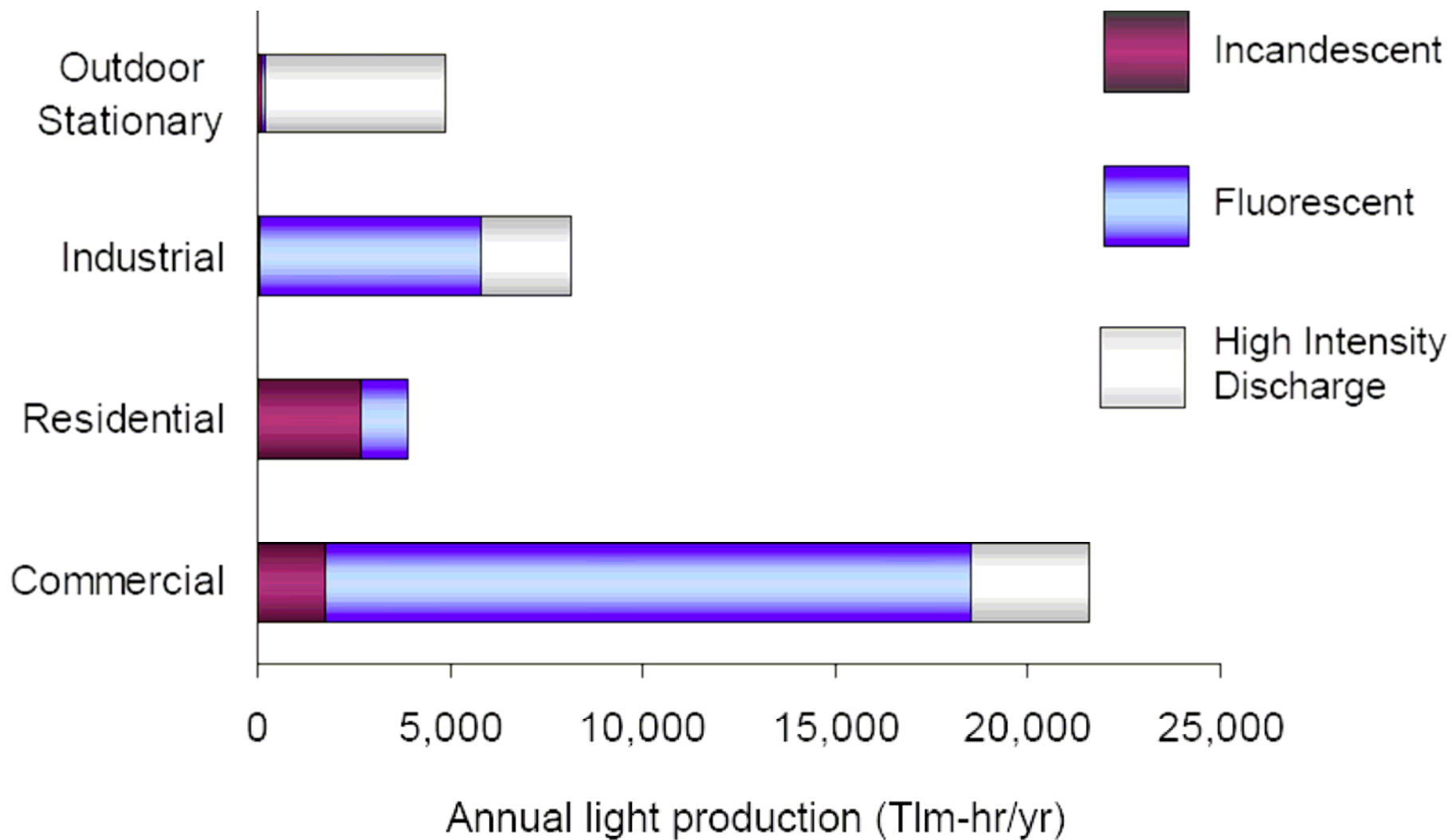


Figure 8-4. Source Light Production by Sector & Source

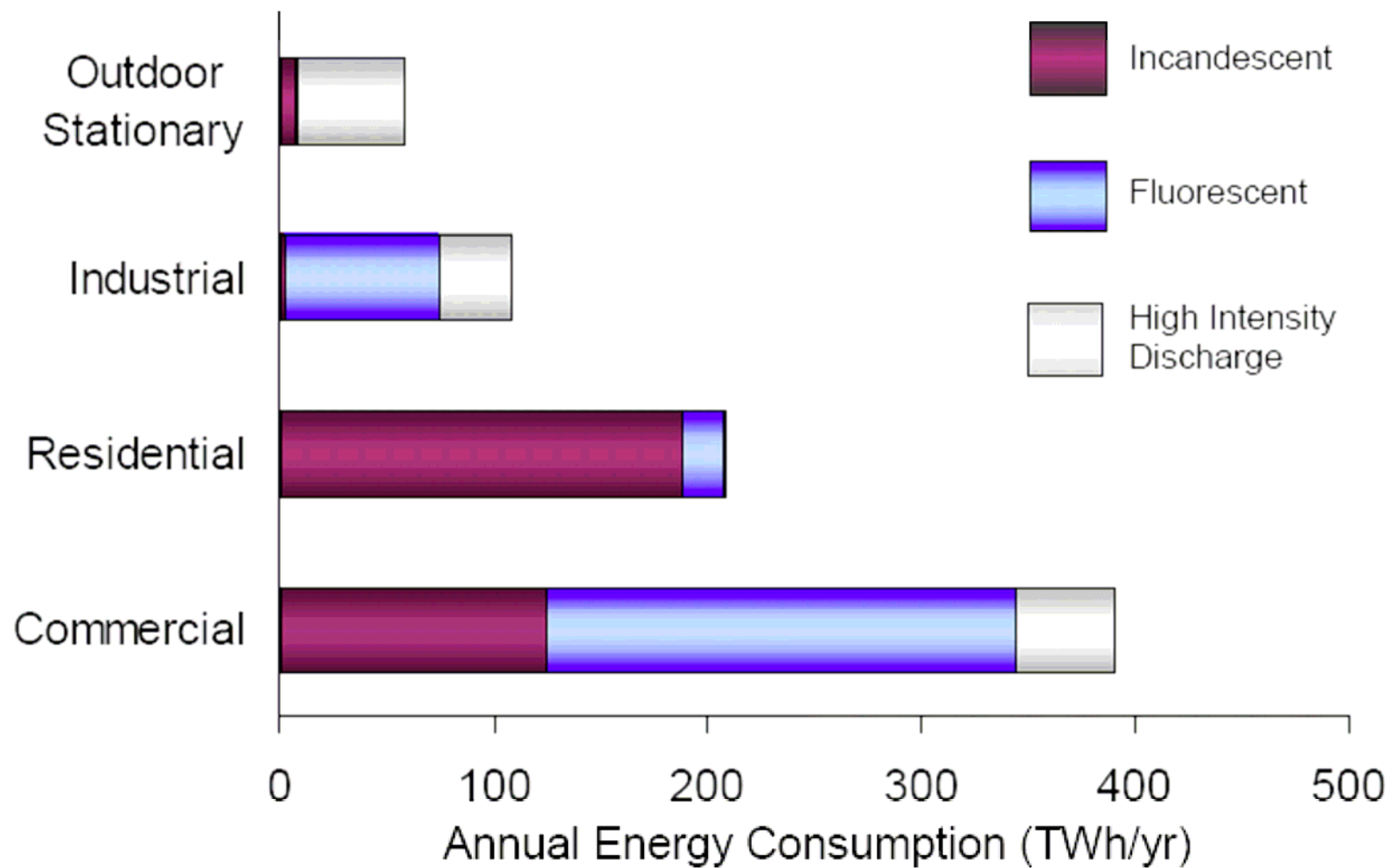


Figure ES-1 Shares of Sectoral Energy Use by Lighting Technology

From "U.S. Lighting Market Characterization", prepared for DOE EERE by Navigant Consulting, 2002

Industrial

Forces Shaping Energy Use

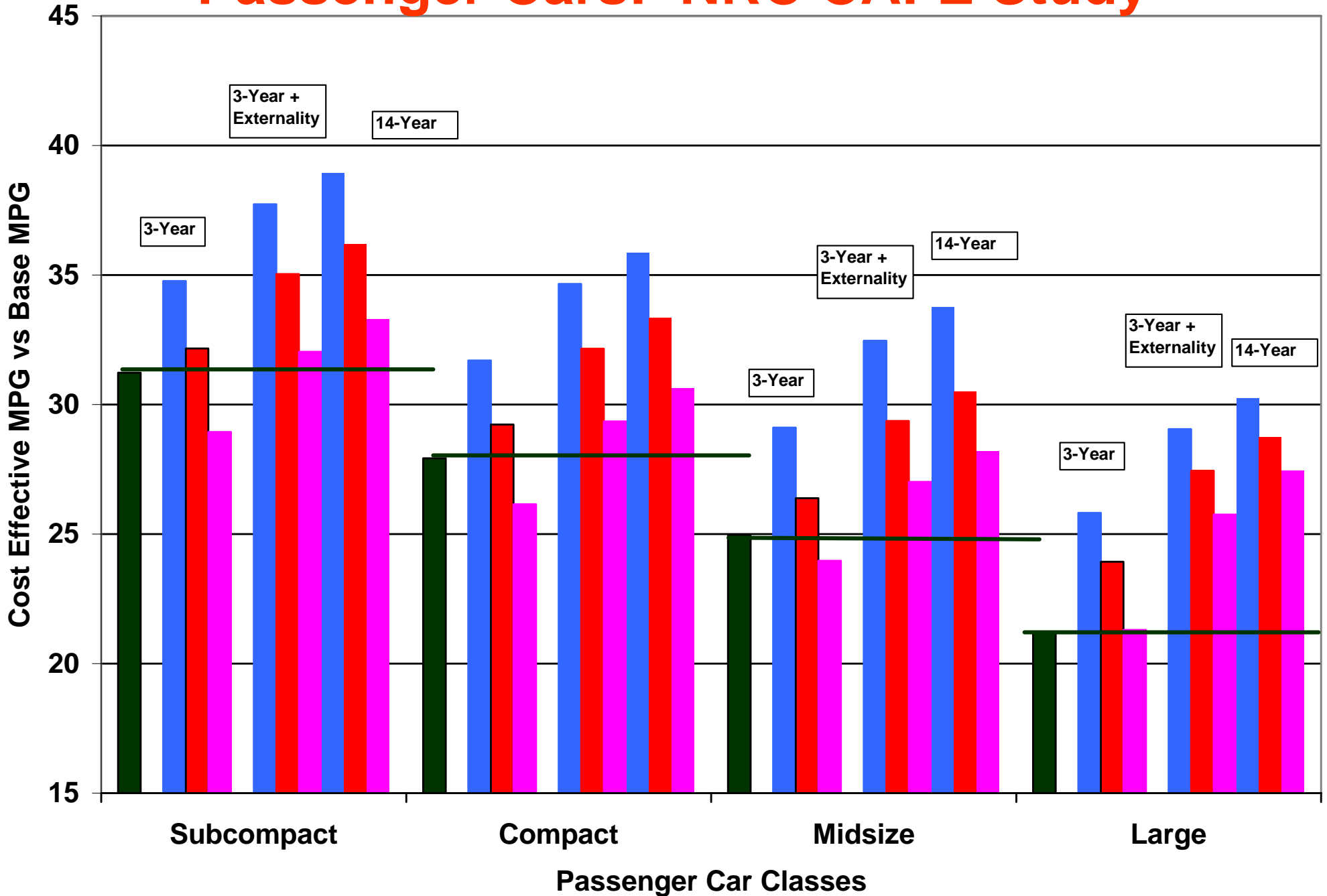
- **Industrial Sector**
 - **Inputs required to produce output**
 - **Level of Economic Output**
 - **Nature of Production Process**
 - **Substitution Among Inputs**
 - **Investment Criteria (interest rates)**
 - **Price sensitive**

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

