Challenges for Long-Term Energy Models: Modeling Energy Use and Energy Efficiency

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34 ! Years

of Energy Information and Analysis

Some Modeling History

- Original Federal Energy Administration Demand Models in PIES and IEES (1974)
  - Residential, Industrial, Commercial Sectors
    - Econometric models
    - Dynamic specification
    - Allowed matrix of own-elasticities and cross-elasticities of demand for PIES and IEES
      - Electricity, Natural Gas, Oil, Coal
  - Designed to examine implications of changes in energy prices, taxes, price regulation
  - For analysis of “energy conservation” options, estimate of direct impacts used as reduction of demand function

Some Modeling History

- Original Federal Energy Administration Demand Models in PIES and lEES (1974)
  - Transportation Sector: Cars and Trucks
    - Vintage Capital Structural Model
      - Vehicle Miles Travelled, MPG of new vehicles, MPG of fleet
      - Econometrically estimated
  - Designed to examine implications of changes in energy prices, taxes, price regulation
  - For analysis of CAFE standards, new car MPG regulations used as inputs, model could directly estimate impacts

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Some Modeling History

- Models continued to evolve
  - Intermediate Future Forecasting System (IFFS)
- Current EIA Demand Models in NEMS
  - NEMS architecture proposed through National Academies Study (1992)
  - Modular Structure allowed demand models to be integrated into modeling system
  - Models become more structural
    - More need for detailed structural data
    - More ability to directly analyze demand-side policies

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Some Modeling History

- Newest Generation of Long-Term Models (Dominantly outside of EIA)
  - Very long term analysis
  - Demand Models almost completely structural
    - Need for very detailed data
    - Little or no econometric estimation
    - Models depend on exogenous time trend in reduced energy use per dollar of real GDP
    - Some detailed energy end use representation
  - Designed to examine implications of greenhouse gas mitigation, transitions to new technologies
    - Most detail on the supply side of models

Modeling Considerations

- What questions will be asked?
  - Energy Efficiency policies
    - Appliance efficiency standards
    - Building standards
    - CAFE standards
  - Impacts of high energy prices
    - High oil prices
    - Carbon prices
  - Impacts of technological changes
    - Endogenous technologies
  - Impacts of changing social norms, possibly motivated by climate change concerns

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Modeling Considerations: Trends/Questions

- Transportation
  - Liquids
  - Shifts to Electricity ?
  - Will hydrogen become viable ?
- Residential and Commercial
  - Growing fraction of energy as electricity
  - Multiples of appliances (refrigerators, printers)
- Industrial
  - Continuing diversity of uses
  - Need understanding/representation of industrial uses

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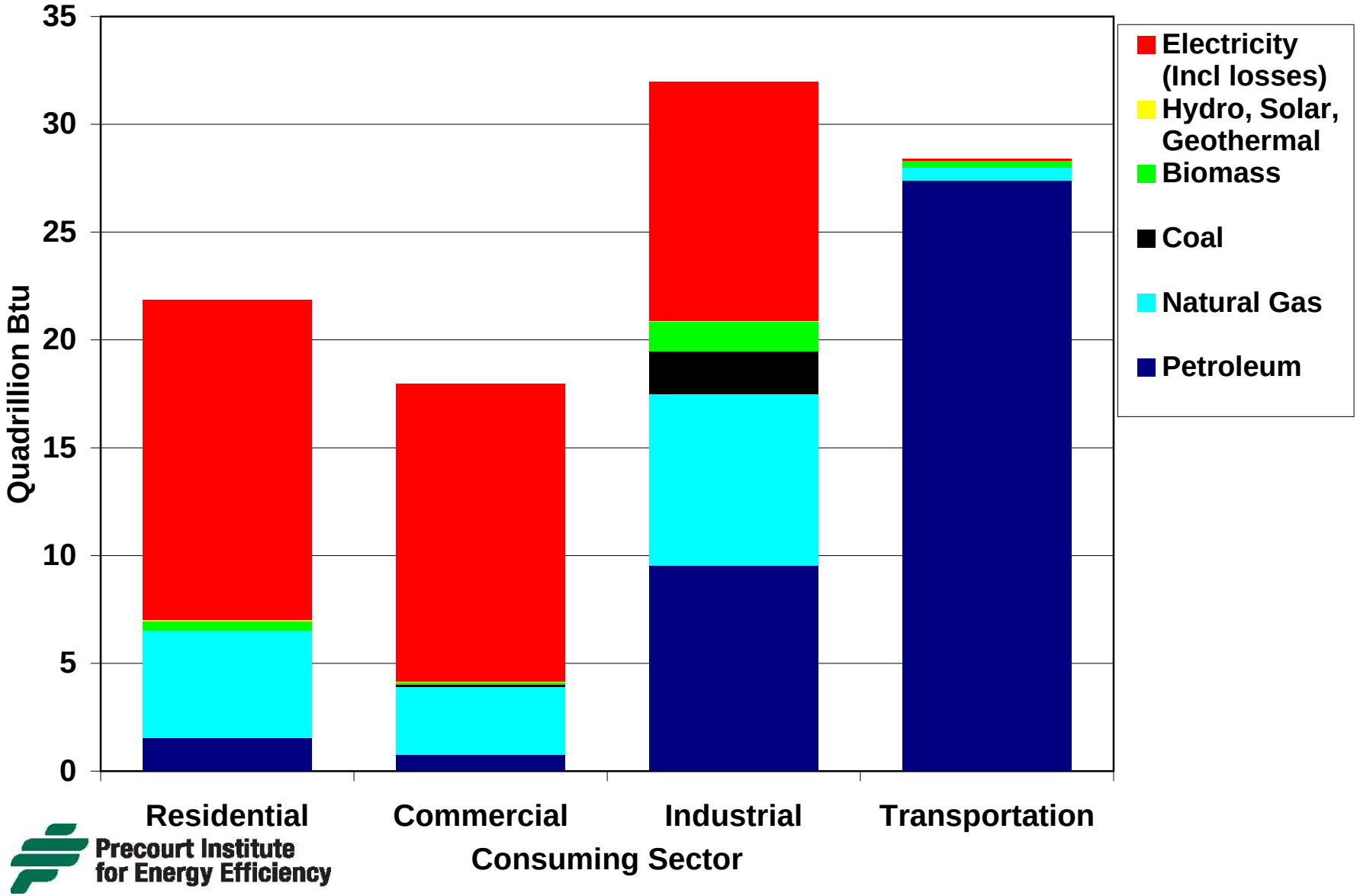
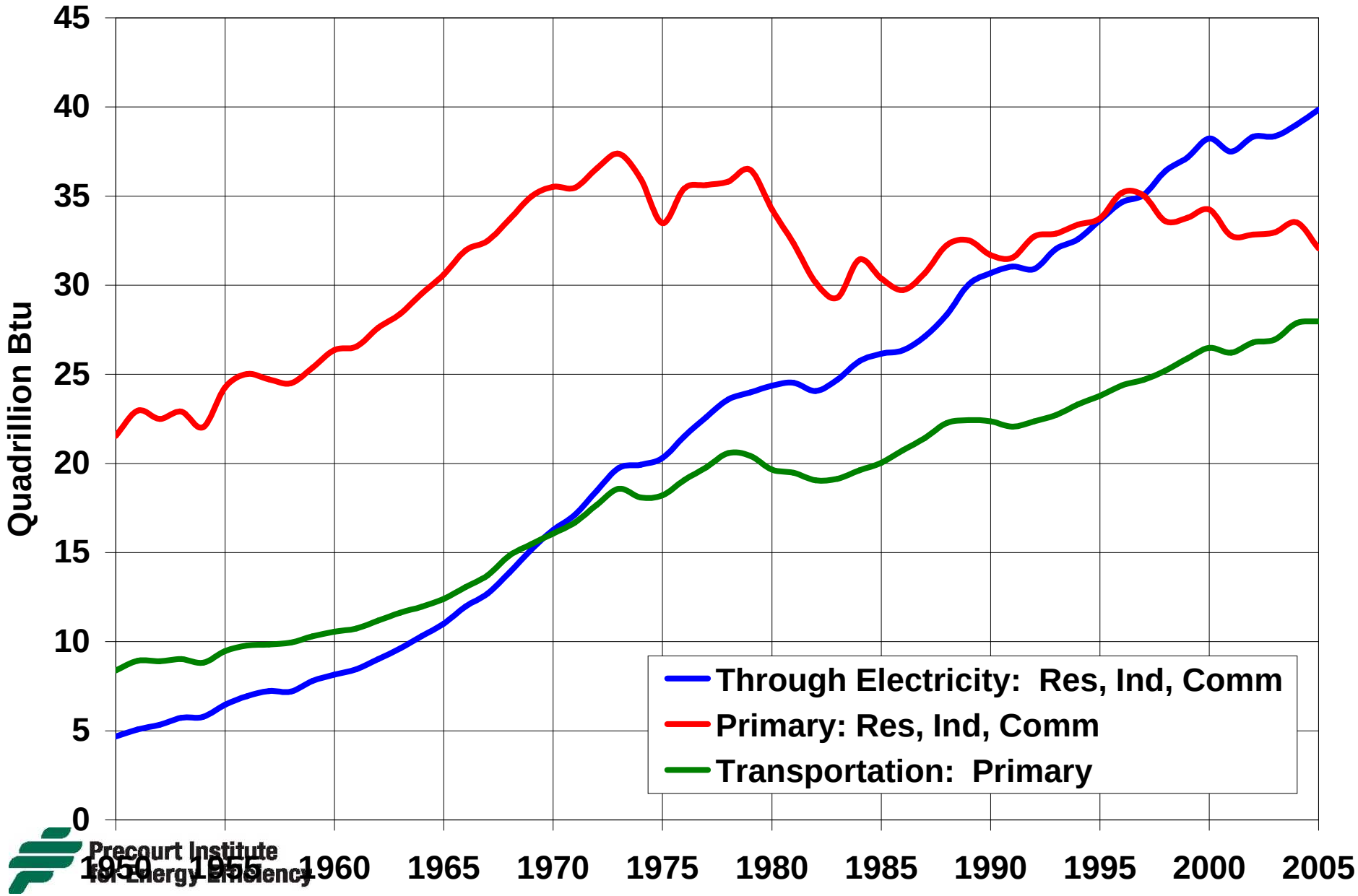
U.S. Sectoral Energy Use: 2005



US Primary Energy and Electricity Use by Sectors



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Technologies

- Existing energy-using technologies
  - Evolution of technologies
  - Intensity of use
- New technologies
  - Invented, but not yet widely adopted
  - Not yet invented

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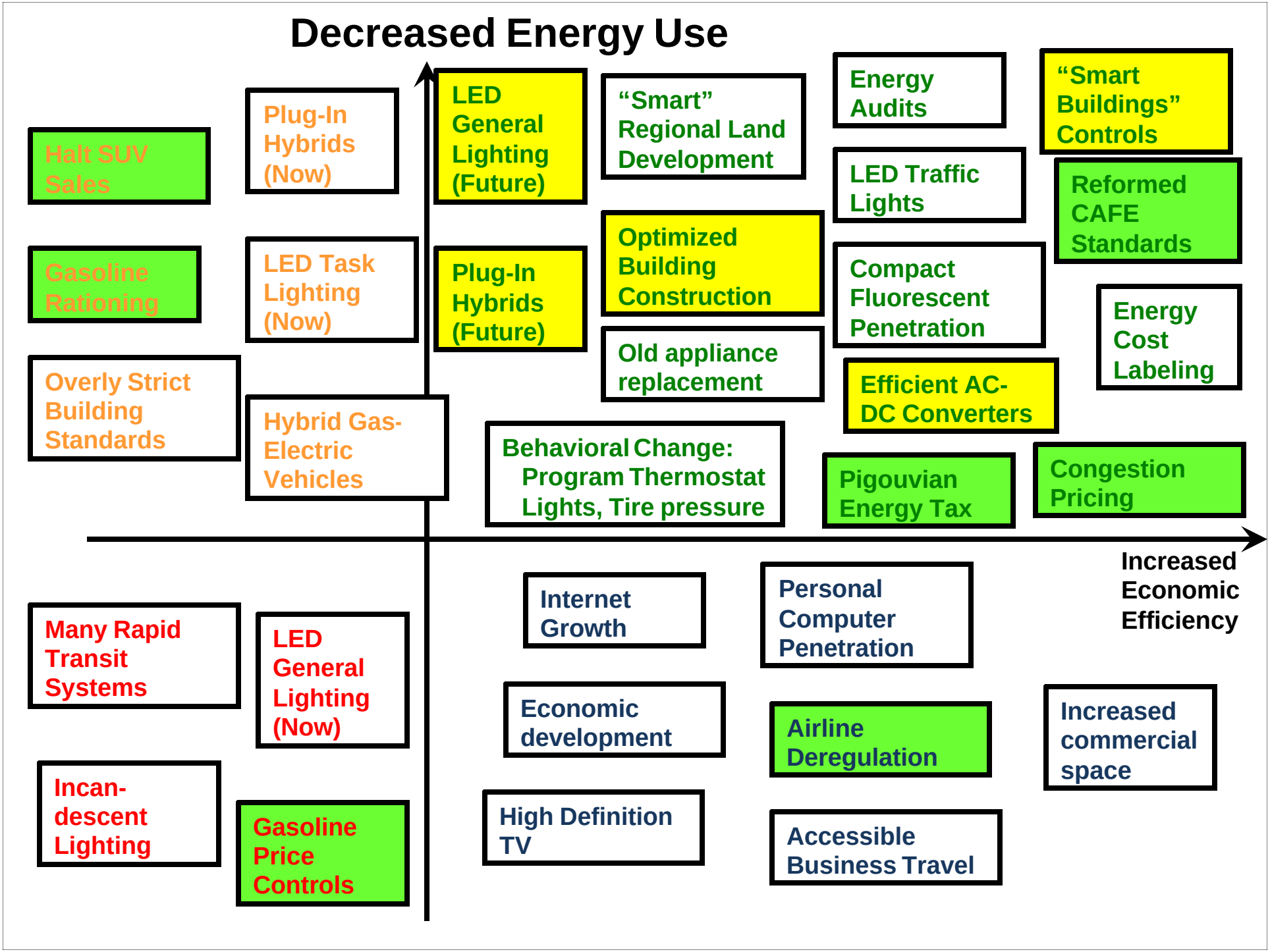
Decreased Energy Use
Halt SUV Sales
Plug-In Hybrids (Now)
LED General Lighting (Future)
"Smart" Regional Land Development
Energy Audits
"Smart Buildings" Controls
LED Traffic Lights
Reformed CAFE Standards
Gasoline Rationing
LED Task Lighting (Now)
Plug-In Hybrids (Future)
Optimized Building Construction
Compact Fluorescent Penetration
Energy Cost Labeling
Old appliance replacement
Overly Strict Building Standards
Efficient AC-DC Converters
Hybrid Gas-Electric Vehicles
Behavioral Change: Program Thermostat Lights, Tire pressure
Pigouvian Energy Tax
Congestion Pricing
Increased Economic Efficiency
Internet Growth
Personal Computer Penetration
Many Rapid Transit Systems
LED General Lighting (Now)
Economic development
Airline Deregulation
Increased commercial space
Incan-descent Lighting
Gasoline Price Controls
High Definition TV
Accessible Business Travel

Uncertainties: Technology

- Vehicles
  - Will hydrogen vehicles become economical?
    - Fuel Cell, On-board storage
  - Will plug-in hybrids or electric vehicles become economical soon?
    - Battery technology
- Buildings
  - Lighting
    - LED
    - New Lighting Uses
  - Integrated Solar
  - Adoption of “smart” building energy controls
- General
  - Learning by doing: magnitudes, generality ?

Example: Lighting Technology

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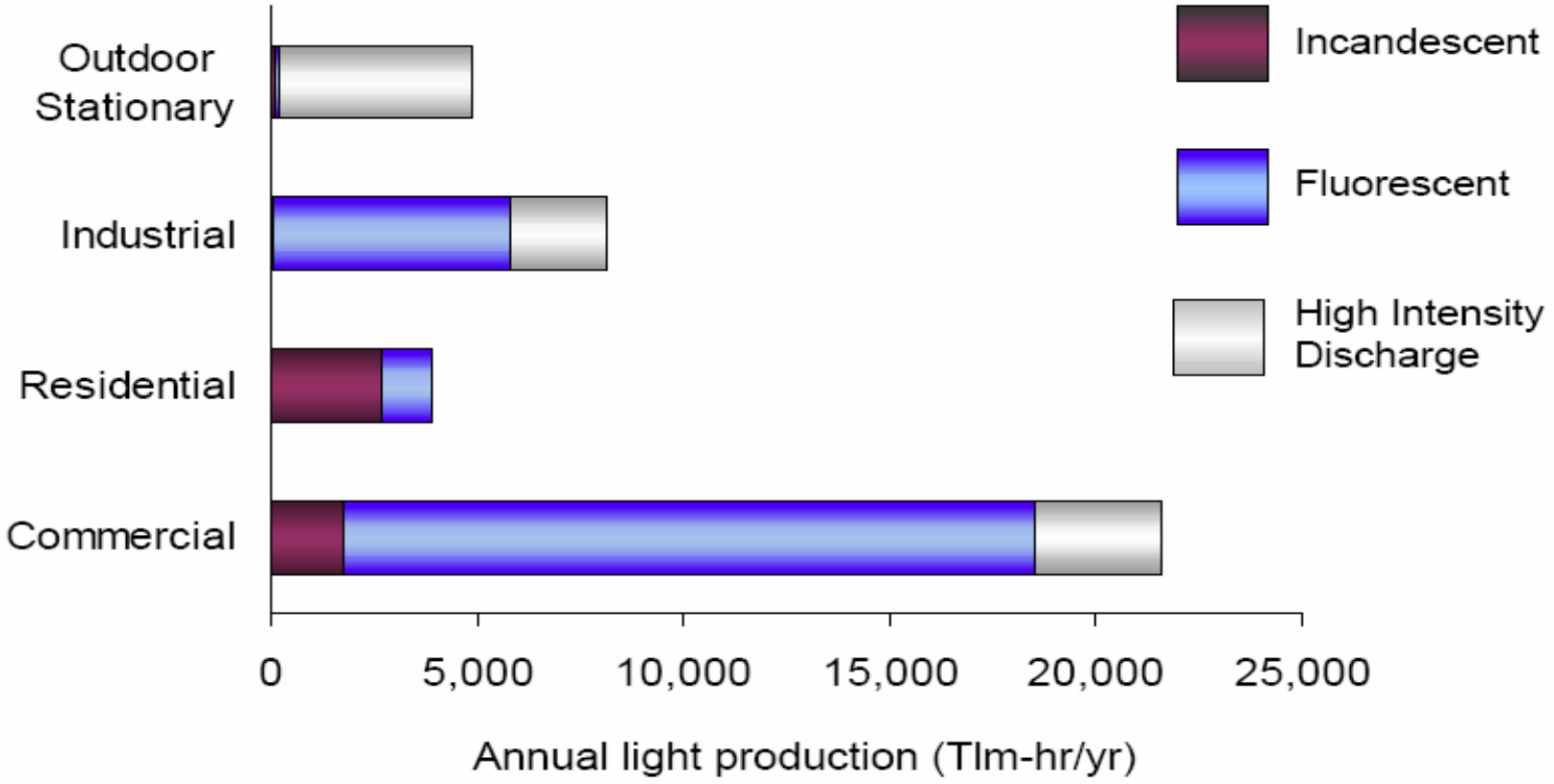

Figure 8-4. Source Light Production by Sector & Source

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

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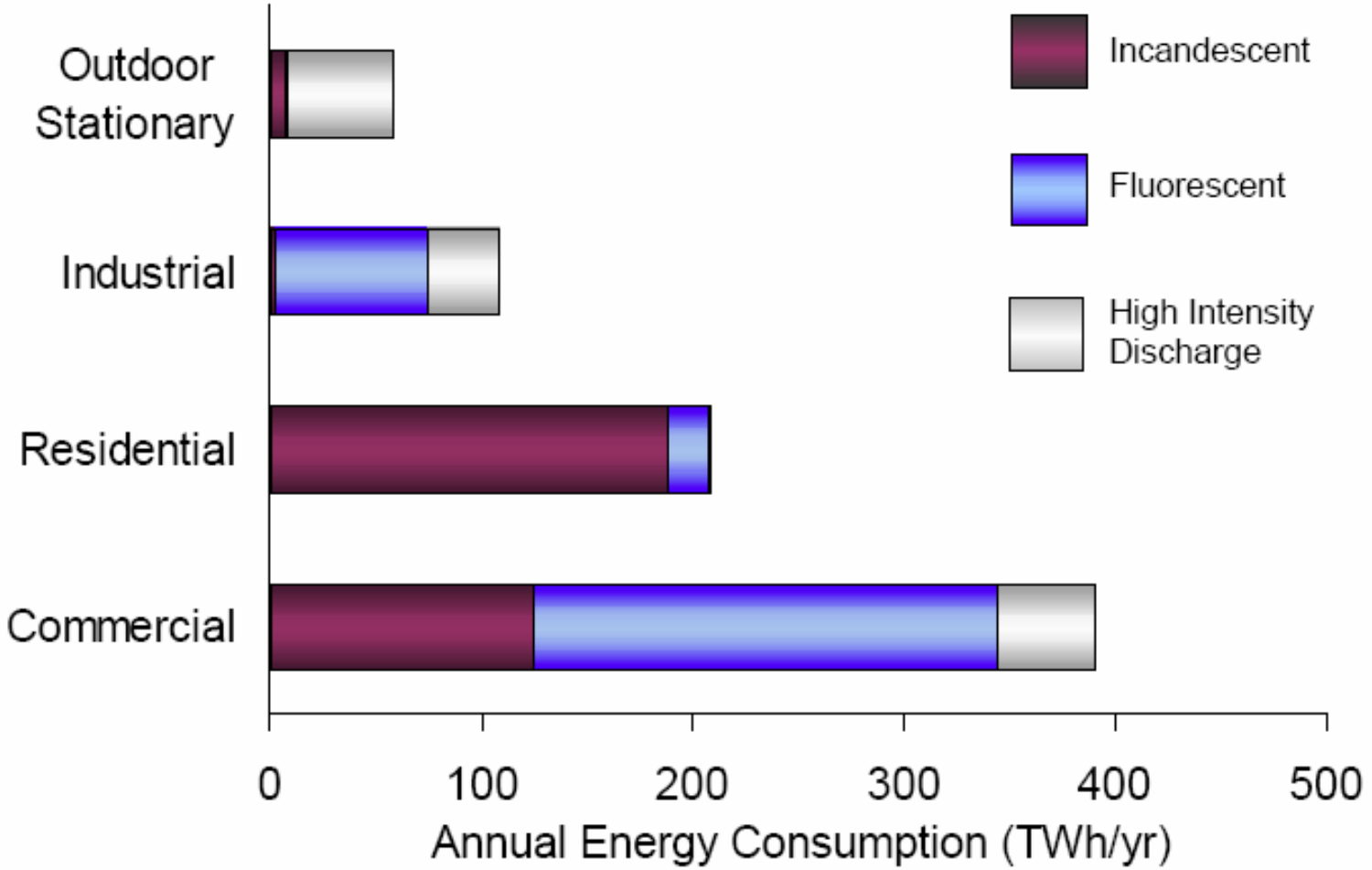

Figure ES-1 Shares of Sectoral Energy Use by Lighting Technology

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

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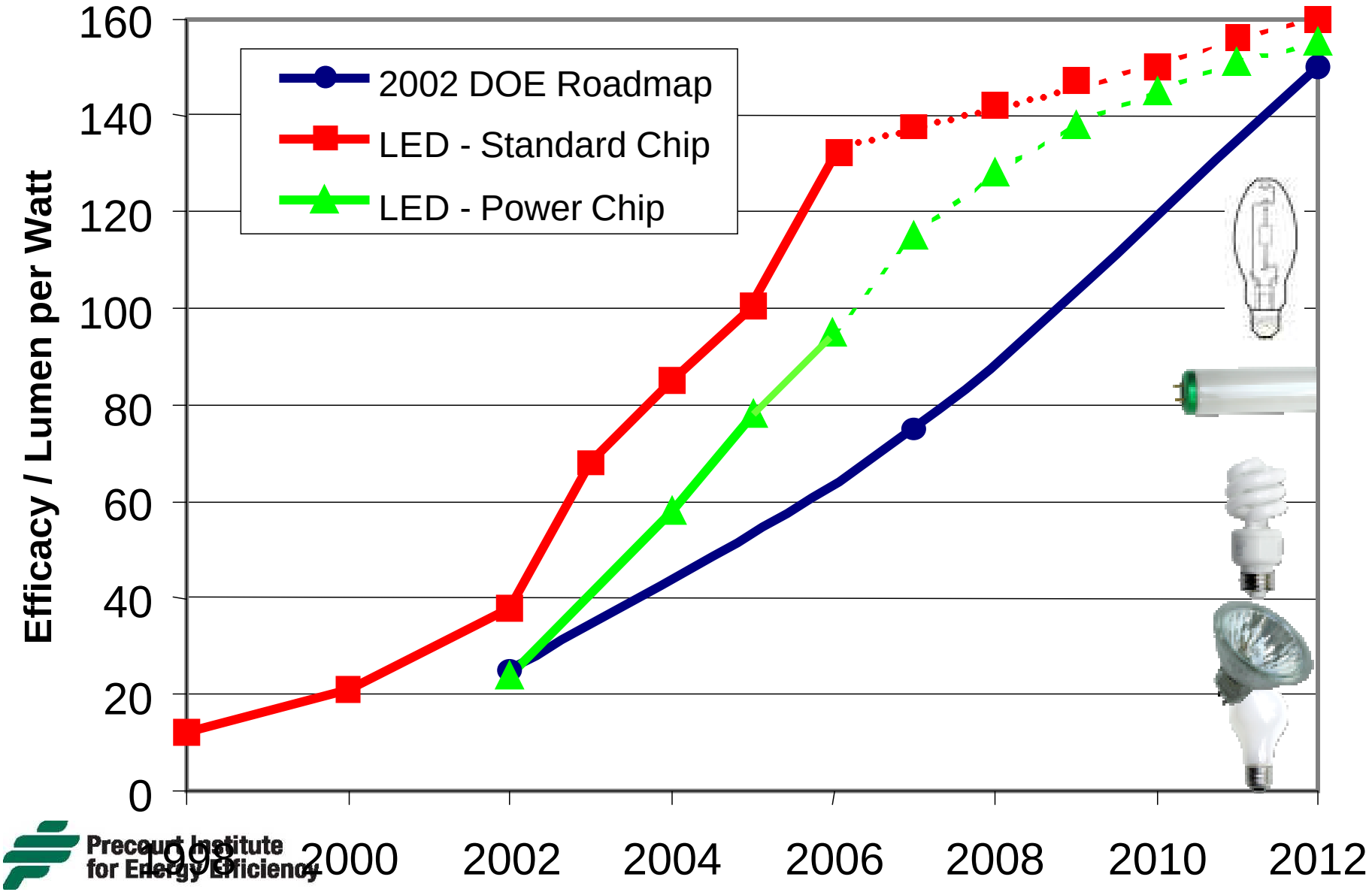
LEDs Efficacy Increases by 30% Per Year



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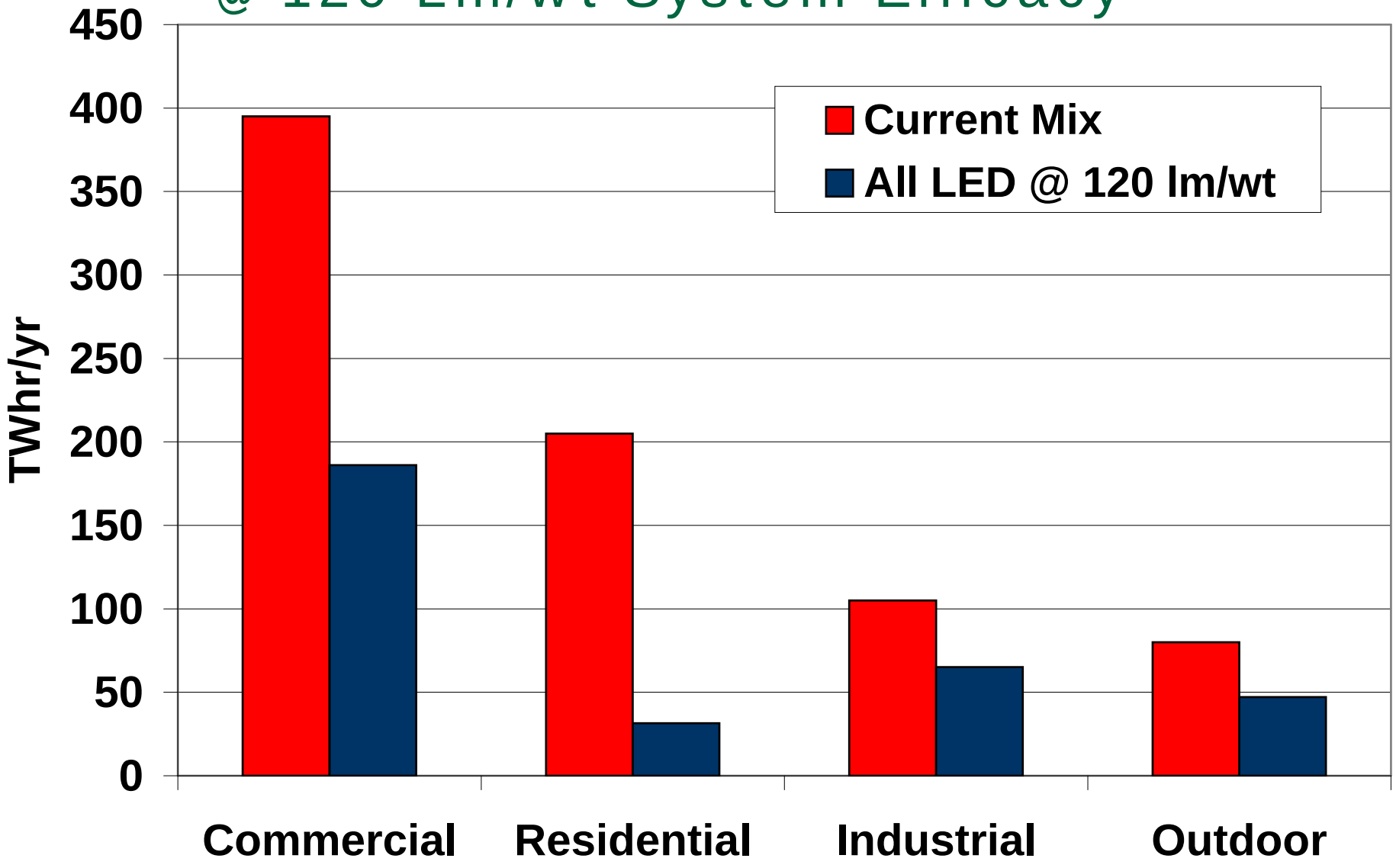
Energy Implications of 100% LEDs @ 120 Lm/wt System Efficacy



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Uncertainties: Behavioral

- Life style changes ? Norms ? Values ?
- Buildings
  - High Energy Use Variability
    - Flat financial optimum
    - LEEDs influence
    - Will norms change to energy efficiency?
    - Incentive and information structure changes
  - Multiple appliances: refrigerators
  - Multiple offices: at work and at home
- Transportation
  - Growth of telecommuting ?
  - Growth of video conferencing ?
  - “Smart Growth” regional growth patterns
- Vehicles
  - Will CAFE standards be the binding constraint?

Modeling Needs: Structure

- More detailed structural models
  - Represent energy services
  - Substitution of capital, energy, energy types to provide energy services
  - Include appliances, buildings, vehicles
    - Need to represent impacts of standards
    - Need to represent changing behavior
  - Need ability to represent intensity of use of energy-using equipment
  - Ability to include behavioral shifts
- Better data to support structural models
  - RECS (more frequent), Other sectors

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Modeling Needs: Uncertainty

- Better representation of uncertainty
  - Probabilistic representation of individual issues
    - Subjective probabilities
    - Communication of these probabilities
  - System-wide probabilistic outcomes
    - Monte-Carlo simulation ?
    - Communication of probability distributions
- Policy Analysis in stochastic models
  - Robust policies
  - Shifts in probability distributions of outcomes
  - Analysis of individual possible outcomes

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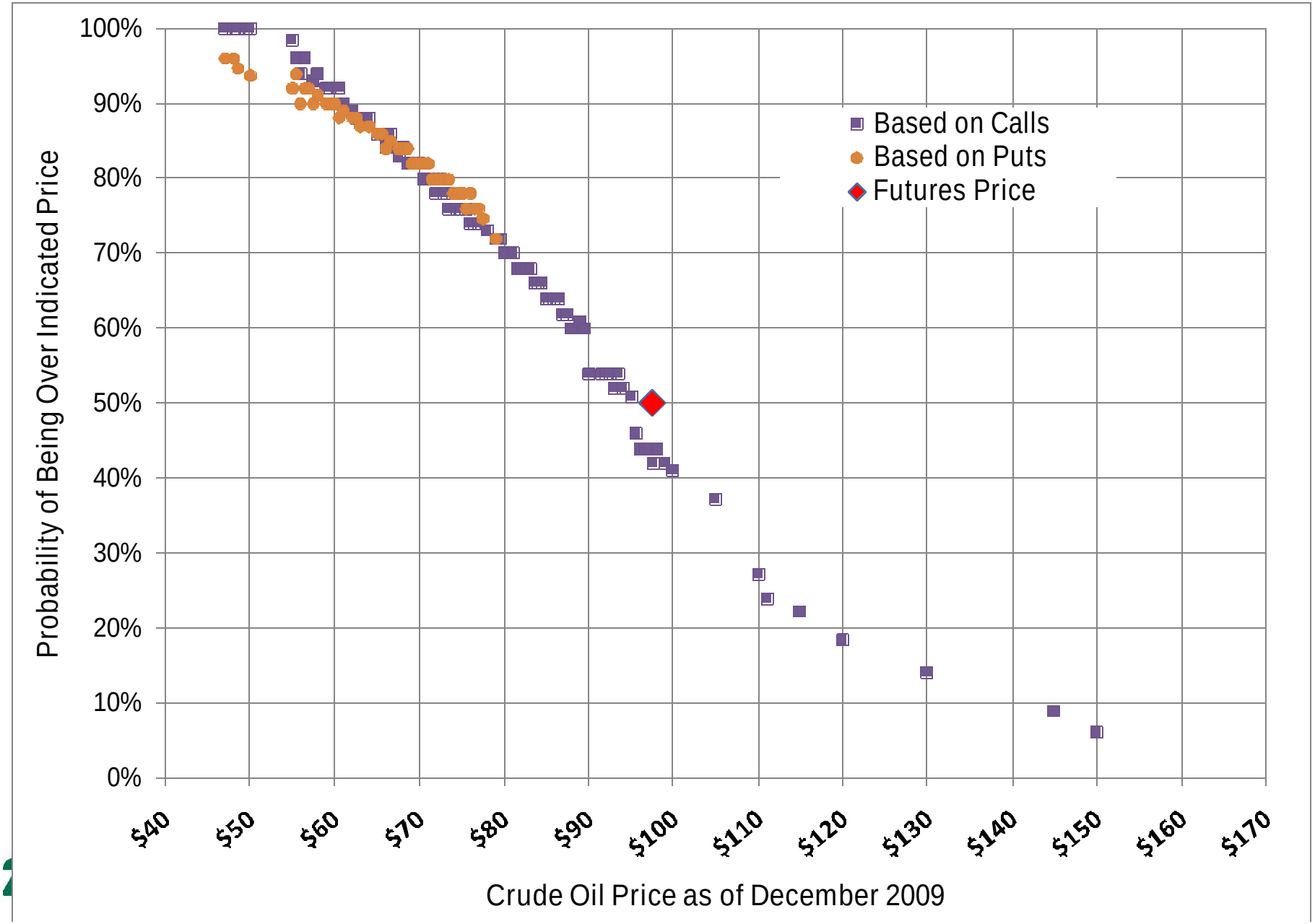
Oil Price Uncertainty December 2009 Delivery (data February 29, 2008)



Modeling Needs: Welfare Measures

- Better Welfare Measures Valuable for Policy Analysis
  - Which outcome is better?
  - Quantities and prices are not sufficient
  - Economic efficiency measures: economic benefits/costs
  - Distributional impacts?
  - Impacts on societal/economic risk
- Efficiency measures will be less controversial than distributional measures (but will still be controversial)

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Trade-offs

- More structural models
  - Might exclude adjustments to changing prices and other conditions
  - May be more complex
  - May be more difficult to interpret
  - May take more time to run
- Stochastic models
  - Will be more difficult to interpret and communicate
  - Will take more time to run
  - More opportunities for alarmism by unsophisticated – or very sophisticated -- users

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