The Demand Side: Behavioral Patterns and Unpicked Low-Hanging Fruit

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Role of Energy Efficiency

- Many scenarios of greenhouse gas mitigation show great importance of reducing growth of energy use. Often referred to as "energy efficiency."
  - Failure to reduce energy use growth requires very large energy supply transformations. Would either need profound supply-side technological changes or would impose very high costs to world economy. Alternatively, failure could doom ability to meet climate goals.
  - Improved energy efficiency could include
    - inventing technologies and practices that provide similar goods or services (e.g. mobility, indoor comfort, light, physical goods) but use less energy
    - changing adoption of such lower-energy using technologies and practices
    - changing consumer and business use of energy-intense goods and services

Modeling Energy Demand

- Improved energy efficiency could include:
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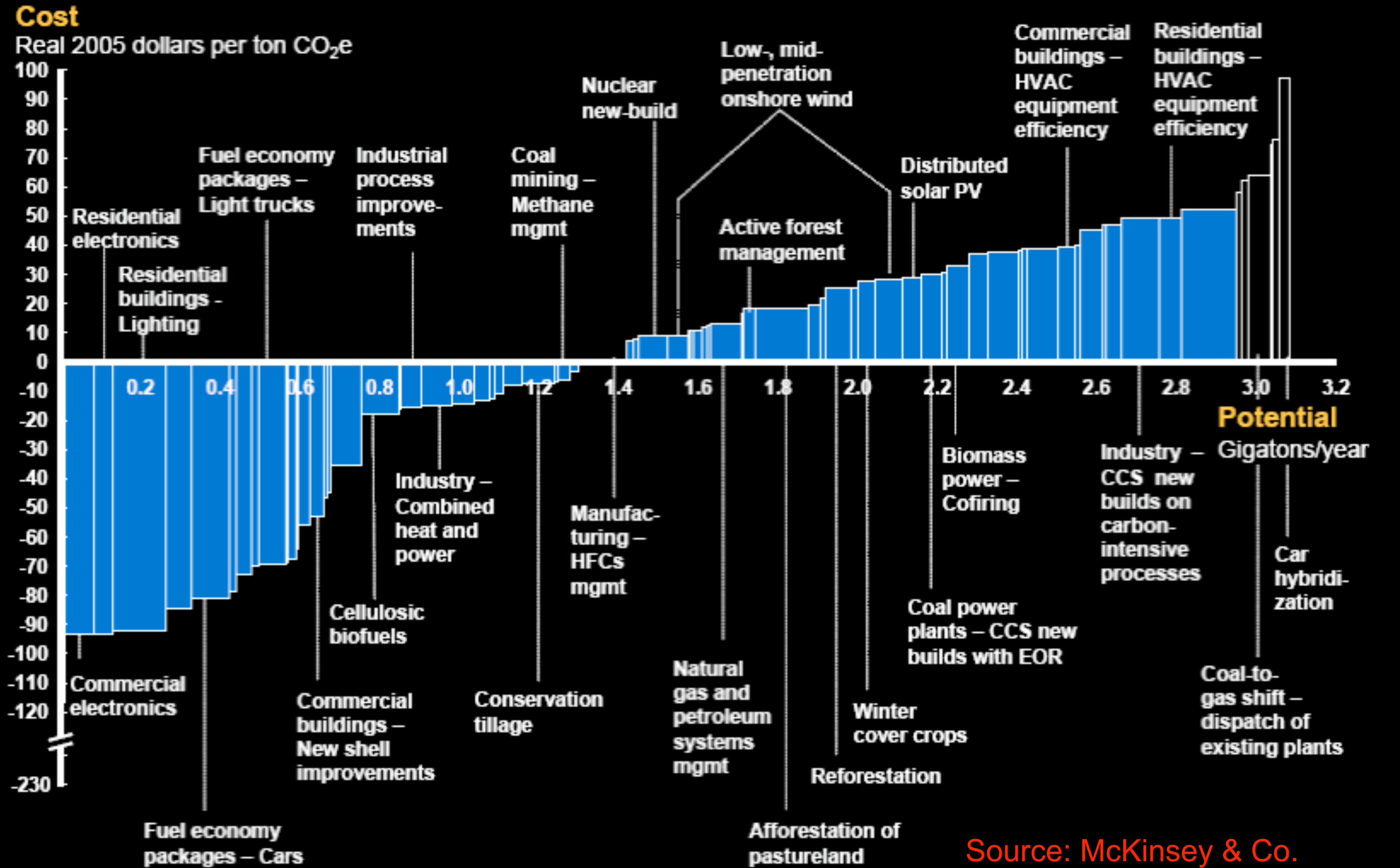
- For projections, need to model results of all three processes.
  - Need to be as serious about demand analysis as we are about supply analysis
- For policy, we need to understand and influence all three processes.

- I will focus on latter two issues today, although issue of invention is crucial to long-term energy efficiency improvement

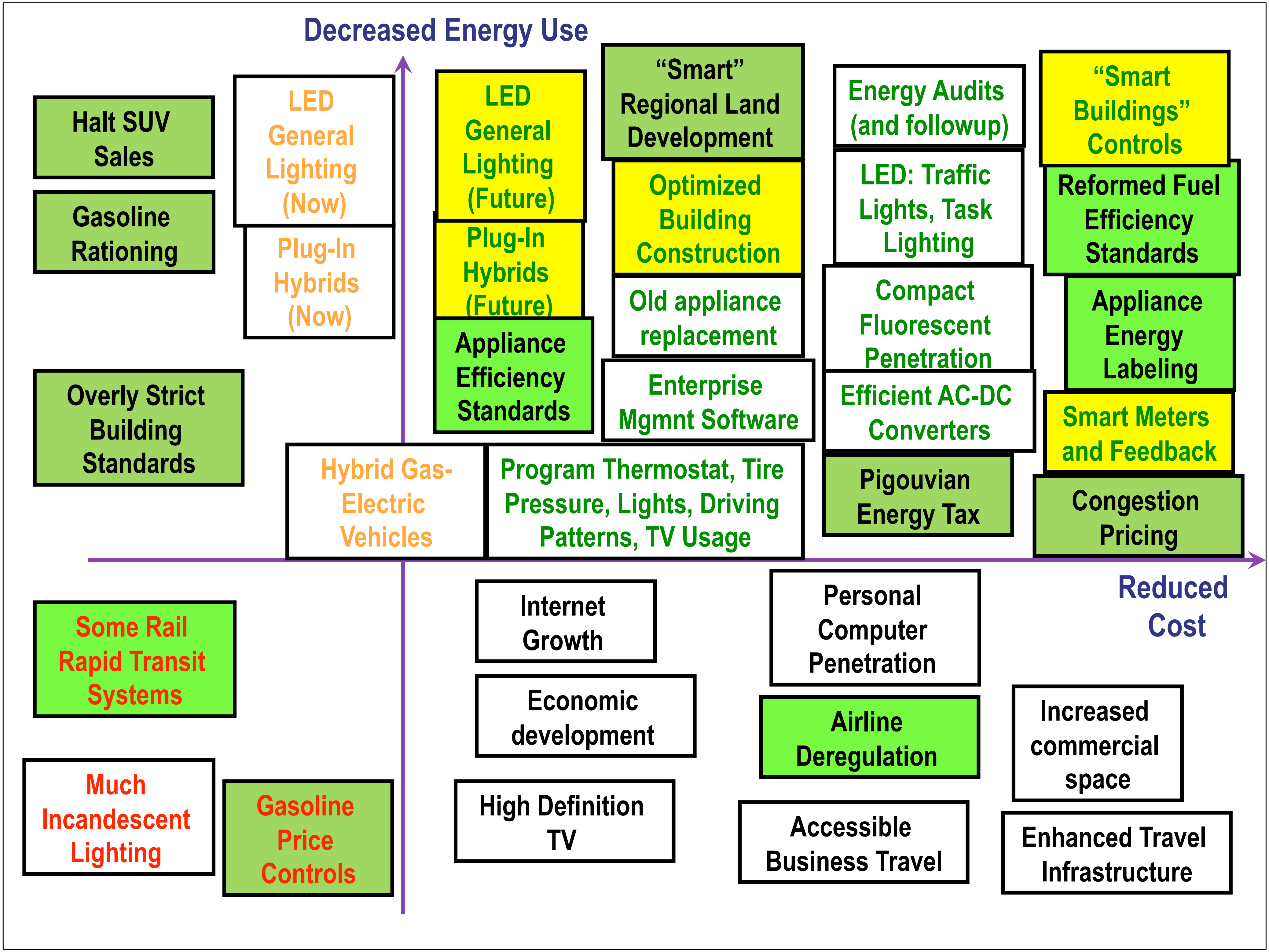
Dichotomy: Modeling vs. Observation

- Dichotomy between
  - Observed energy use
  - Estimates of economically optimal energy use or economically optimal supply curves for energy efficiency
- Typically show that optimal energy use is smaller than observed energy use in many applications
  - Recommendations for energy efficiency policy
    - E.g. Vattenfall/McKinsey work
    - Low-hanging fruit

GHG reduction opportunities widely distributed – 2030 mid-range case



Source: McKinsey & Co.



Decreased Energy Use
Reduced Cost
Halt SUV Sales
Gasoline Rationing
LED General Lighting (Now)
Plug-In Hybrids (Now)
LED General Lighting (Future)
Plug-In Hybrids (Future)
Appliance Efficiency Standards
"Smart" Regional Land Development
Optimized Building Construction
Old appliance replacement
Enterprise Mgmnt Software
Energy Audits (and followup)
LED: Traffic Lights, Task Lighting
Compact Fluorescent Penetration
Efficient AC-DC Converters
"Smart Buildings" Controls
Reformed Fuel Efficiency Standards
Appliance Energy Labeling
Smart Meters and Feedback
Overly Strict Building Standards
Hybrid Gas-Electric Vehicles
Program Thermostat, Tire Pressure, Lights, Driving Patterns, TV Usage
Pigouvian Energy Tax
Congestion Pricing
Some Rail Rapid Transit Systems
Much Incandescent Lighting
Gasoline Price Controls
Internet Growth
Economic development
High Definition TV
Personal Computer Penetration
Airline Deregulation
Accessible Business Travel
Increased commercial space
Enhanced Travel Infrastructure

Dichotomy: Modeling vs. Observation

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- Typically show that optimal energy use is smaller than observed energy use in many applications
  - Recommendations for energy efficiency policy
    - E.g. Vattenfall/McKinsey work
    - Low-hanging fruit
  - Challenges for mathematical modeling of energy use
    - Econometric models fitted to actual use
    - Optimization models (least cost) need “adjustments,” “calibration,” or less kindly, “fudge factors.”
      - E.g. practice of increasing sector-specific discount rate in optimization models to fit data

- **Why the dichotomy?**

  or

- **Why does low hanging fruit remain unpicked for decades?**

- **If it is truly low hanging fruit, how can we pick it?**

Optimal Energy Use: Basic Economic Theory

- Consumer
  - Utility function is fixed
  - Consumer has complete information about mapping from action to consumption quantities
  - Consumer has complete information about prices and therefore complete information about mapping from consumption quantities to costs
  - Utility does not depend on choices of neighbors
  - Maximizes utility
- Firms
  - Production possibility set is fixed at any point of time, although may change over time
  - Firm choses input and output quantities to maximize profits

Integrated into Most General Equilibrium or Optimization-Based Energy Models

- Basic Economic Theory
- Other than energy markets, typical markets are operating competitively with perfect information
  - Energy markets may be treated as imperfectly competitive
- No information or transaction costs for consumers or firms

- Note: Reduced form econometric models may be inconsistent with these elements of traditional economic theory.
- But then welfare implications of equilibrium may not correspond to those of Arrow-Debreu general equilibrium theory.

Observations Often Not Represented in Energy Models

Externalities

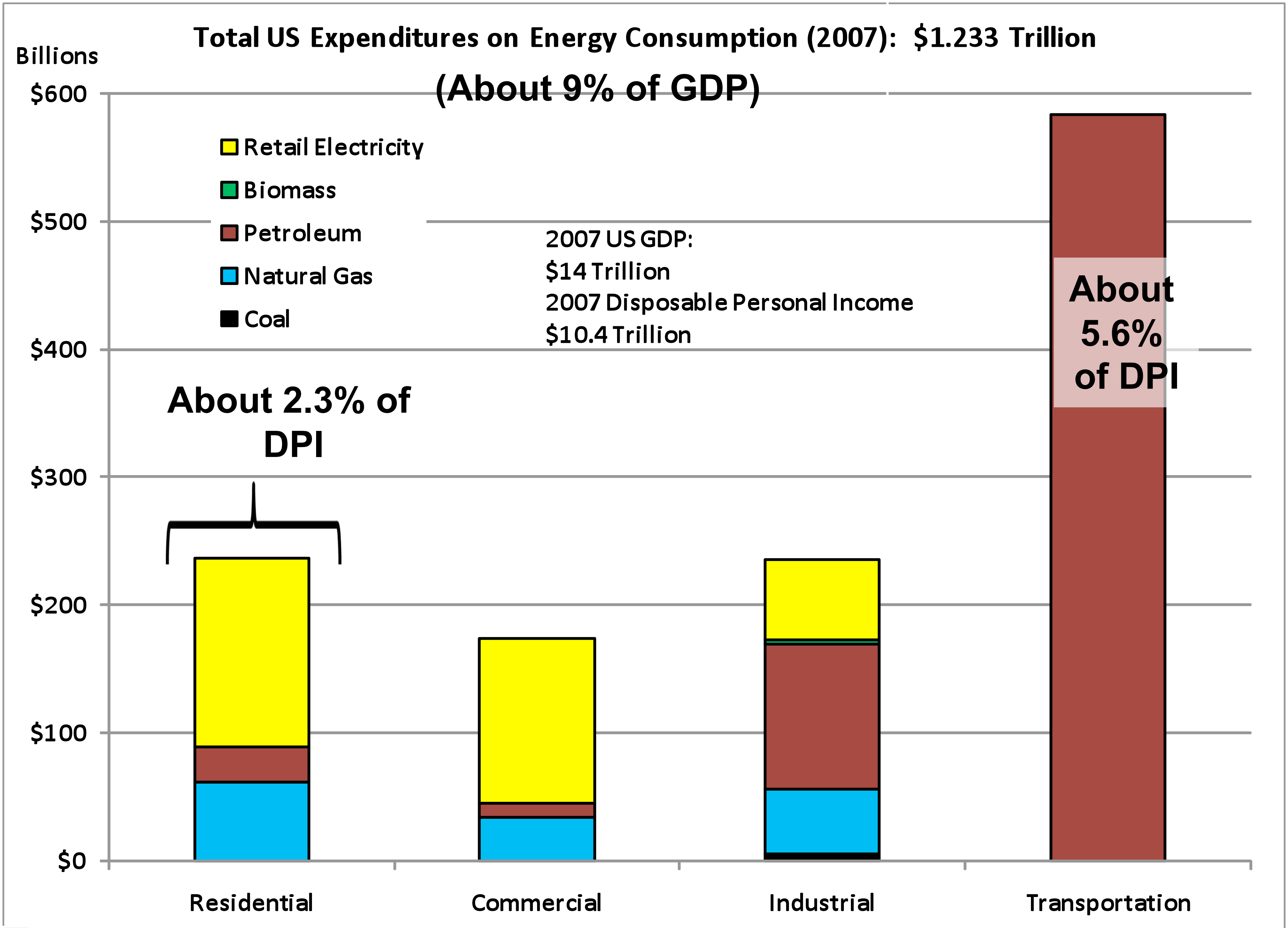
- Environmental and other externalities do exist
- Lead to over-use of polluting technologies
  - Too much driving (congestion, environmental, security)
  - Vehicles not efficient enough absent regulation (environmental, security)
  - Overuse of electricity (environmental)
- These issues are basically easy to integrate into models, except when spatially or temporally heterogeneous
  - E.g. highway congestion
- In principle, externalities can be integrated into models and analysis; in practice, how can they be included well?
- If they are not included, interpret as market operating without internalizing externalities. But will political forces lead to internalization of such externalities?
  - E.g. air pollution in China from coal-fired generators

Product Differentiation

- Modeling may group heterogeneous products and evaluate as if they were homogeneous. Similarly, people are heterogeneous.
- Product characteristics may vary in ways that makes a specific product optimal for some people and inferior for others.
  - Compact fluorescent lights appear cost effective relative to incandescent lights. But light quality differs. Delay to full light intensity differs. Style of device differs.
    - For some people, energy cost differences dominates; for others product characteristic differences dominates.
  - Fuel-efficient vehicles may differ in luxury, comfort, style, towing ability from less fuel efficient vehicles.
  - Will consumers see electric vehicles as equivalent to liquid-fueled vehicles
- In principle, product differentiation can be integrated into models and analysis; in practice how can this be included well?

Energy Demand Observations

- Consumer: Low salience of residential energy cost
  - Poor information about energy use of alternatives
    - Large effort – transactions costs -- would be required to determine differences in energy use and thus in energy costs
  - Often limited cognitive skills
    - Plasma TV vs. LED TV. What does it take to estimate the DPV of energy costs over life of TV – even if you know your discount rate?
  - Electricity is low fraction of income
    - Possible savings for each decision are even smaller fraction of income. Is it worth effort to optimize?
    - Is it likely that small differences in product characteristics will dominate financial differences?
  - Buying food in market. Salience?



Electricity includes non-primary energy costs of electric system

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Energy Demand Observations

- Many energy-using commodities on market have technical characteristics that do not minimize discounted present value of usage cost plus first cost (for any reasonable interest rate).
  - Bias toward minimizing purchase cost
  - Consumer: Low salience. Little information about operating cost, but purchase price obvious. Motivation for manufacturers to supply products with technical characteristics that minimize first cost at expense of discounted present value of purchase plus operating cost.
- Examples:
  - Digital recorder box for cable TV service
  - AC/DC converters; small appliance battery chargers

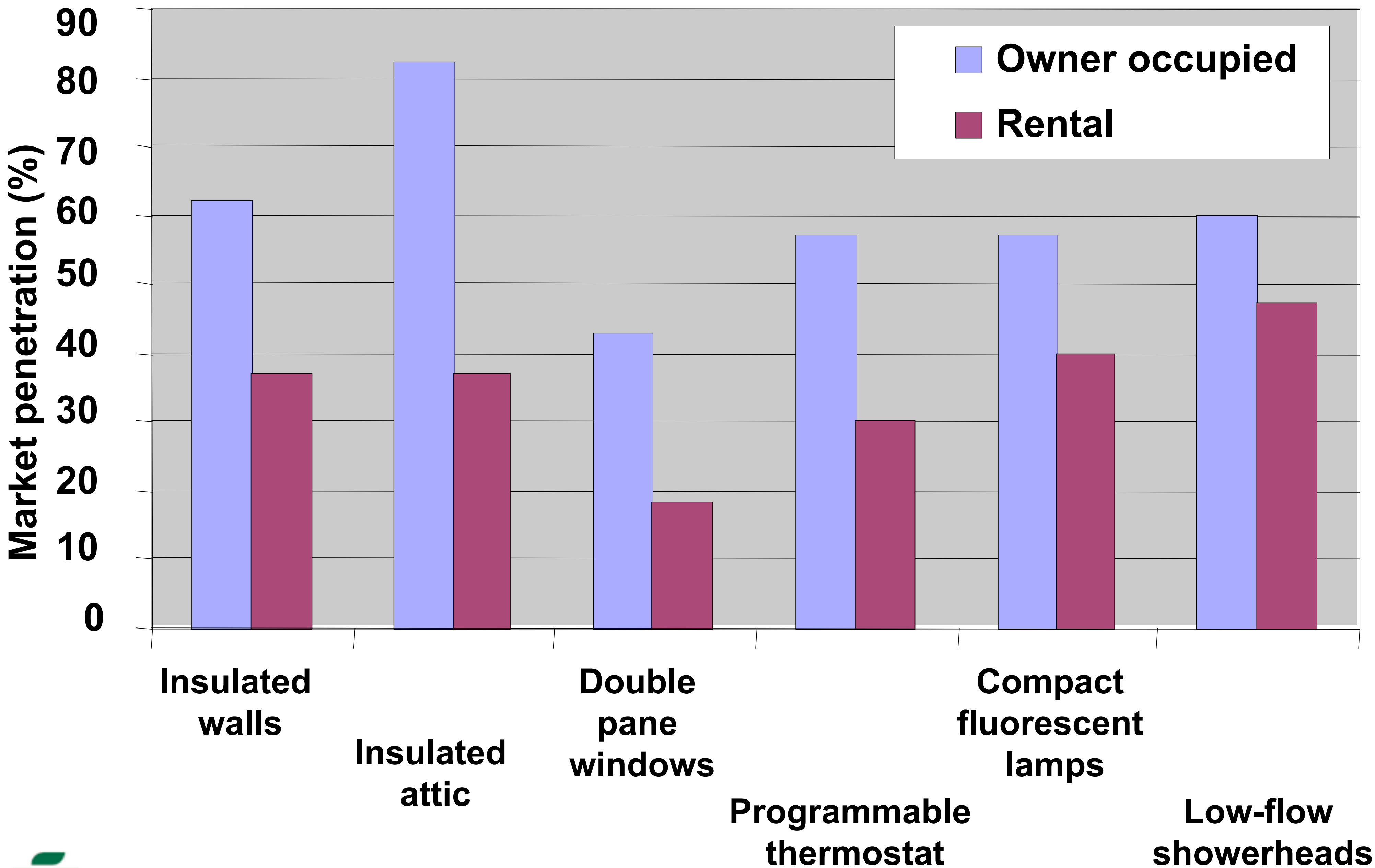
Energy Demand Observations

- Individual household use of energy is influenced by data on energy use by neighbors or others in peer groups.
- Example:
  - OPower provides comparison between individual and the neighbors. May reduce electricity use by around 5% for those that use more electricity than the neighbors.
  - Stanford/Google experiment shows whole house real-time electricity use data can reduce use by around 5%, but effect is temporary
- With low salience of economic factors, other motivations are relatively more important.
  - What social message is given by driving a small, fuel efficient car?
    - Message different among cultures? E.g. France, Italy, Belgium, vs. United States; Or Germany? US blue states vs. red states?

Energy Demand Observations

- **Implementation of energy efficient technologies in residential sector depends on mode of housing tenure (rental vs home ownership)**

Market Penetration of Energy Efficiency Measures in Owner-Occupied and Rental Housing in California (CEC 2004)



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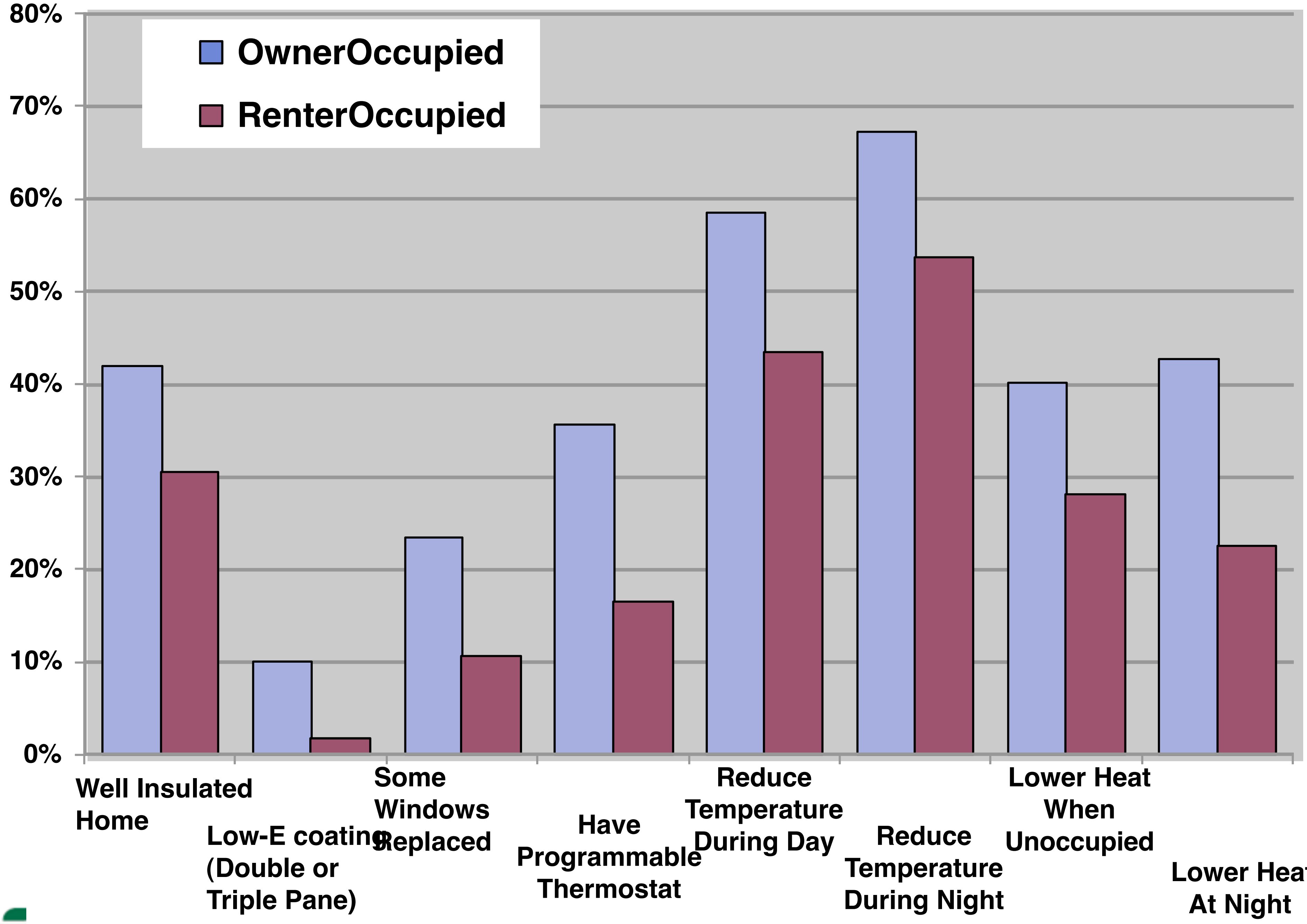
Fraction of Homes With Efficient Technologies or Behaviors



Source: Calculated from the 2005 RECS survey, by Anant Sudarshan

Energy Demand Observations

- Implementation of energy efficient technologies in residential sector depends on mode of housing tenure (rental vs home ownership)
  - I interpret as a principal/agent problem between landlord and tenant
  - Poor information is likely a key issue.
  - I interpret as inconsistent with the typical general-equilibrium or bottom-up modeling practice: Other than energy markets, typical markets are operating competitively with perfect information

Energy Demand Observations

- If corporations focus managerial attention on energy use, can reduce energy costs profitably (savings > cap costs)
  - Dow Chemical example
  - Eric Schmidt (Google example)
- Most companies organized by product lines, treat energy use as an overhead item for most business units
  - Incentives for managers to devote attention only to non-overhead items; implies non-optimal choice of overhead items – including energy
- Enterprise software allows companies to reduce cost of finding profitable energy cost reductions
  - Hara, C3, SAP
- Thus model of firm choosing optimal inputs and outputs, ignoring managerial incentives and information products may underestimate energy use

Diffusion Processes

- **New products and practices can diffuse slowly in the market.**
  - **Speed of diffusion depends on social network communication, advertising, motivating suppliers, peer-group communications, communications from children to parents, regulations, etc.**
  - **With slow diffusion process cannot expect to see quick 100% market penetration of any new product**
- **If products continually get better, not optimal to replace capital stock immediately when cost-effective. That would preclude even better product. Optimal waiting time to replace.**

Barriers to Optimality

Institutional Barriers	Market failures	Behavioral Issues
	Externalities: Usage; R&D	Low salience of energy issues ???
Structure of crafts for building construction	Principal/Agent Problems	Principal/Agent Problems
Limited modeling tools for building design	Poor Information about Prices and Energy Use	Poor Information about Prices and Energy Use
Organization of Corporations	Incomplete markets for energy efficiency	Managerial Priorities
	Systems Issues (E.g. Chicken & Egg)	Lack of Energy-Related Information Systems
Distortionary regulatory and fiscal policies		Cognitive Skills

Modeling for Policy

- If models ignore these economic observations, they still can be used for policy analysis, but not directly.
  - Need to do a separate analysis of the impacts on demand and then alter the demand functions
  - Process is not straight forward
  - Easier to simply do analyses of policies with explicit policy handles built in model.
    - Does this lead to a problem of "looking under the lamp post for lost keys"?
      - Compare:
        - » How many modelers include consideration of such behavioral factors?
        - » How many include response to a carbon price?

Policy Interventions

- Moving away from modeling issues to policy interventions.

- There is not just one problem
  - Therefore there is not going to be a single solution
- Can we match solutions to the particular problems?

- One Solution: Go beyond the economics

"It runs on its conventional gasoline-powered engine until it senses guilt, at which point it switches over to battery power."

Some Motivational Approaches

- Pricing
  - A carbon price would have pervasive effects on energy use in all sectors
  - However, carbon prices will not address many of the market failures nor the information and cognitive issues
  - Navy experiment with base housing: benchmarks and charges or payments for deviations in energy use from the benchmarks
  - Gasoline taxes in Europe vs US motivate purchase of smaller more fuel efficient vehicles

Some Motivational Approaches

- Information
  - Labeling; e.g. Energy Star
  - Building performance rating and rating disclosure.
    - E.g., California mandatory building ratings
  - Easily processed economic data
- Information systems
  - New genre of enterprise-wide energy and carbon accounting and management software.
    - E.g., C3, Hara. Make it less costly to find energy efficiency options in large distributed organization, allow central management of energy and carbon savings, allow alignment of incentives with management energy goals

Other Motivational Approaches

- Feedback (immediate information linked to decisions)
  - Smart meters, sensors, energy information appliances
  - Google/Stanford experiment with Google Powermeter
  - Three levels of possible feedback
    - Consumer use of appliance/technology
    - Consumer purchase of appliance/technology
    - Manufacturer supply of appliance technology

Other Motivational Approaches

- Stochastic Rewards
  - Balaji Prabhakar congestion experiment with Infosys in Bangalore, India
  - Goal: incentives for Infosys commuters to travel at uncongested times
  - Infosys employees given chance for one month extra salary each time they took bus to arrive one half hour earlier than rush hour, two chances for arriving one hour earlier.
    - Expected value per ticket was 20 rupees – 10 cents.
    - Roughly 15% of employees decided to come one-half hour or one hour early.

Other Motivational Approaches

- Social norms
  - Billing information that compares electricity use to neighbors or other norms. E.g. OPower mailings.
  - Navy housing experiments mentioned in last slide

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