Behavioral Concepts and the National Energy Modeling System

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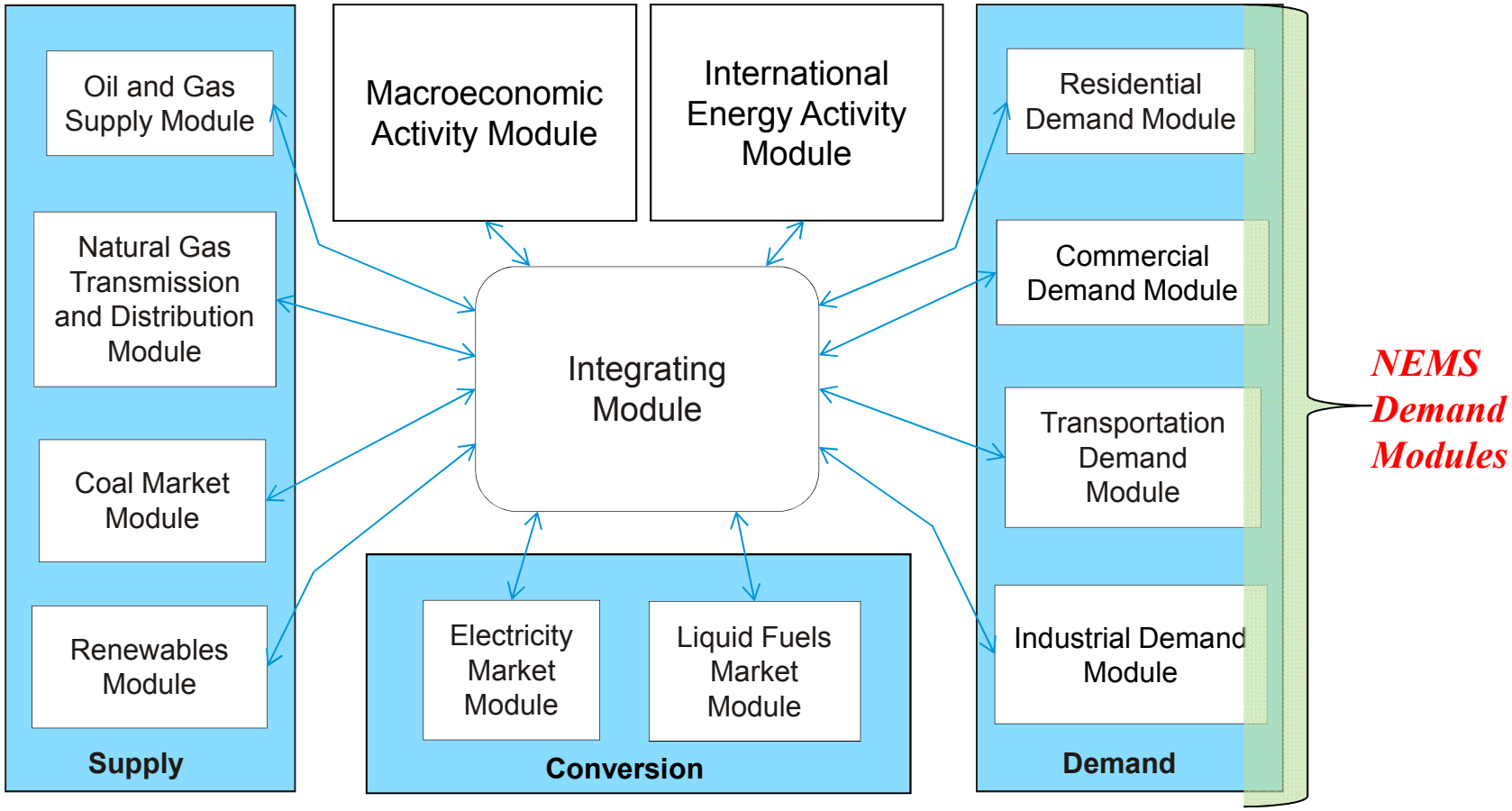
Overview

- EIA, as the independent provider of energy data and analysis for the U.S. government, uses a national scale integrated model of the energy system called NEMS; four system modules represent end use sectors (transportation, industrial, commercial and residential)
- EIA research into behavioral economics concepts since 2011 has emphasized aggregate demand and alternative methods
- Two public releases so far:
  - Proceedings of EIA technical workshop held in August 2013
  - New, extensive contractor report (November 2014)
- Findings to date support EIA's overall end use methods, while highlighting importance of issues and suggesting key areas for further research

The National Energy Modeling System uses a modular structure that builds demand up from end uses and capital equipment

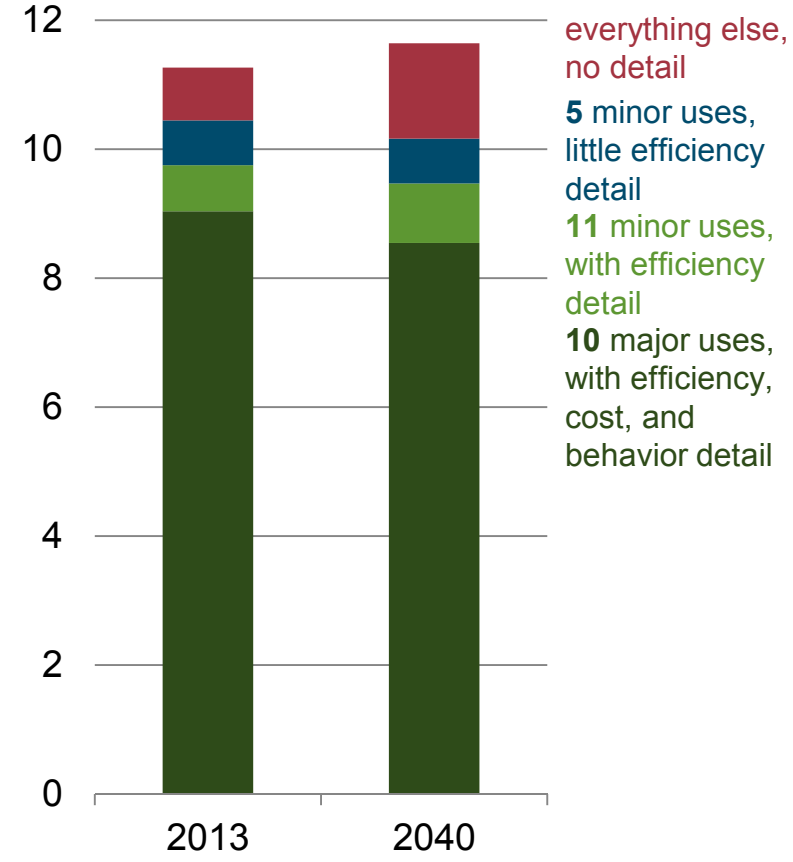


Behavioral representation in the NEMS framework

- Mathematical construct that treats demand as occurring only via specified end use services, as mediated by specified installed equipment
- Cost and performance characteristics of equipment specified independently of behavioral parameters
- Behavior influences both purchase decisions for new capital and the level of end use demand as determined by fuel prices, weather, etc.
- In practice, this equates to *hurdle rates* (implicit discount rates) and *short-term elasticity parameters*

Market shares and technology detail in the residential sector (RDM representation)

residential consumption by end use group
quadrillion Btu



Source: AEO2013 Reference case

- *Major equipment and shell measures (80% in 2013)*
  - *Cost, efficiency, behavior, equipment interaction, fuel switching*
- *Minor uses (13%)*
  - *ENERGY STAR electronics*
  - *Some have efficiency detail (TVs, PCs) and some don't (secondary heating, coffee makers, security systems)*
- *"Everything else" (7%)*
  - *Essentially a remainder from bottom-up approach*

Residential market share calculation for equipment

$$Weight_{equipment} = e^{B1*CapitalCost+B2*OperatingCost}$$

$$Weight_{Class} = \sum Weight_{equipment}$$

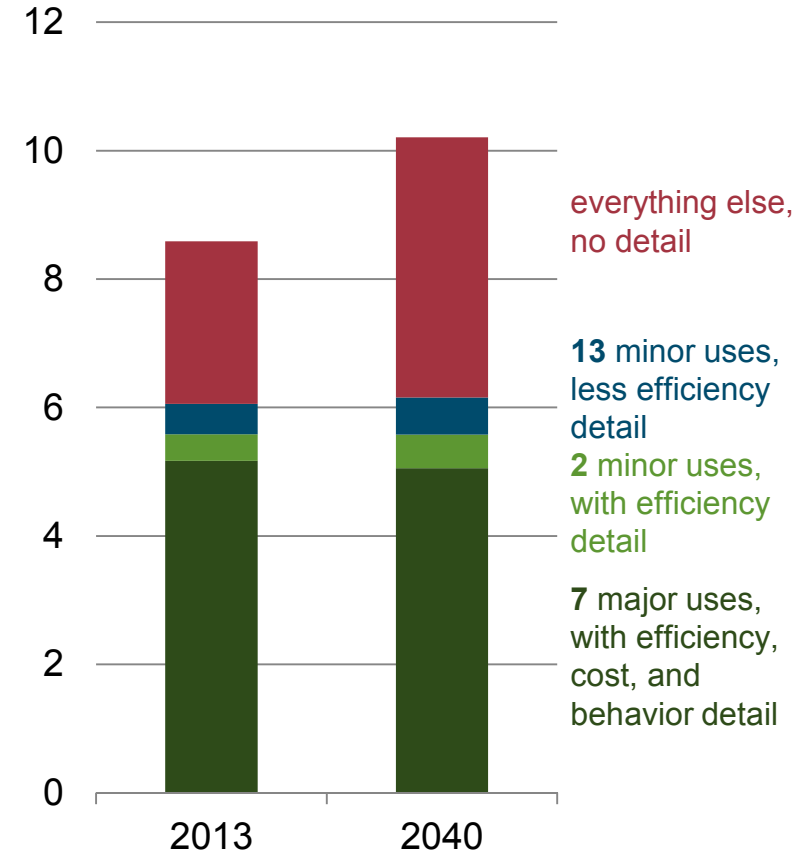
$$MarketShare_{equipment} = (Weight_{equipment}) / (Weight_{Class})$$

B1, B2
together provide
Implicit discount rate

- *Provides share of an equipment type within an equipment class*
  - *End uses: heating, cooling, water heating, cooking, refrigeration, etc.*
  - *Classes (heating, for example): electric furnace, gas furnace, distillate furnace, LPG furnace, etc.*
  - *Types: different models of electric furnace, different models of gas furnace, etc.*

Market shares, technology detail in the commercial sector (CDM representation)

commercial consumption by end use group
quadrillion Btu



Source: AEO2013 Reference case

- *Less homogenous*
- *Major equipment (60% in 2013)*
- *Minor uses (11%)*
- *"Everything else" (29%)*

Commercial consumer risk-adjusted time preference premium distribution, 2014-2040

Commercial Consumers' Time Preference Premium to the Risk-Free Interest Rate	Shares of Specific Energy End Uses Subject to Each Premium Level						
	Heating	Cooling	Ventilation	Lighting	Water Heating	Cooking	Refrig-eration
∞ (represented by 1000%)	26.5%	26.4%	26.5%	26.4%	26.3%	26.1%	26.2%
100%	22.6%	22.5%	22.6%	22.5%	24.9%	24.8%	24.8%
45%	19.6%	19.3%	19.6%	19.3%	21.2%	21.4%	21.3%
25%	19.2%	19.2%	19.2%	19.3%	16.9%	17.1%	17.0%
15%	10.5%	10.6%	10.5%	8.5%	9.7%	9.7%	9.7%
6.5%	1.3%	1.6%	1.3%	1.3%	0.6%	0.5%	0.6%
0.0%	0.3%	0.4%	0.3%	2.7%	0.4%	0.4%	0.4%

Note: risk-free interest rate is represented by the 10-year Treasury note

Fuel price response in both RDM and CDM

- Fuel prices provided each model year by the other NEMS modules
  - Changes in fuel prices are measured relative to the base year
- Hurdle rates/beta parameters respond to fuel price changes
  - Rising fuel prices result in decrease in nonfinancial portion of hurdle rate or change in beta parameter to represent increasing importance of fuel costs
  - Option for price-induced technology change, but not used in Reference case
- Short-term price elasticity affecting use of equipment
  - Effect of each elasticity-induced change spread over the current model year and the following two years
  - Modified for elasticity for efficiency 'rebound effect': increases in efficiency can lead to increased amount of service demand (small magnitude)

EIA's research and outreach on behavioral economics broadly supports NEMS framework

- The pragmatic use of calibration to historic electric sales data determines the implicit discount rate structure in NEMS
- Invariant and uniform consumer preferences, a common feature of the 'old' neoclassical paradigm, are already made flexible in this model specification—at least in principle
- Application of further flexibility, or generally more heterogeneous behavioral assumptions, is analytically tractable in NEMS on some dimensions
- The analytic question becomes, what difference might it make? How much demand variance might be at stake?

Example alternate aggregate demand specifications from EIA behavioral economics report (November 2014)

- Sparsity-Based or Bounded Rationality. Consumers have only a limited set of perceived options, and only 'jump' to another choice when large enough changes in prices, etc. accumulate. Also fits a price threshold/round number model.

- Segmentation of Demand. Consumers have a very lumpy preference distribution, and can even be grouped into 'families' or types based on collections of characteristics such as income, education, other purchase choices, lifestyle etc. Segmentation may vary from choice to choice, end use to end use, or along other dimensions.

Alternate demand specifications continued

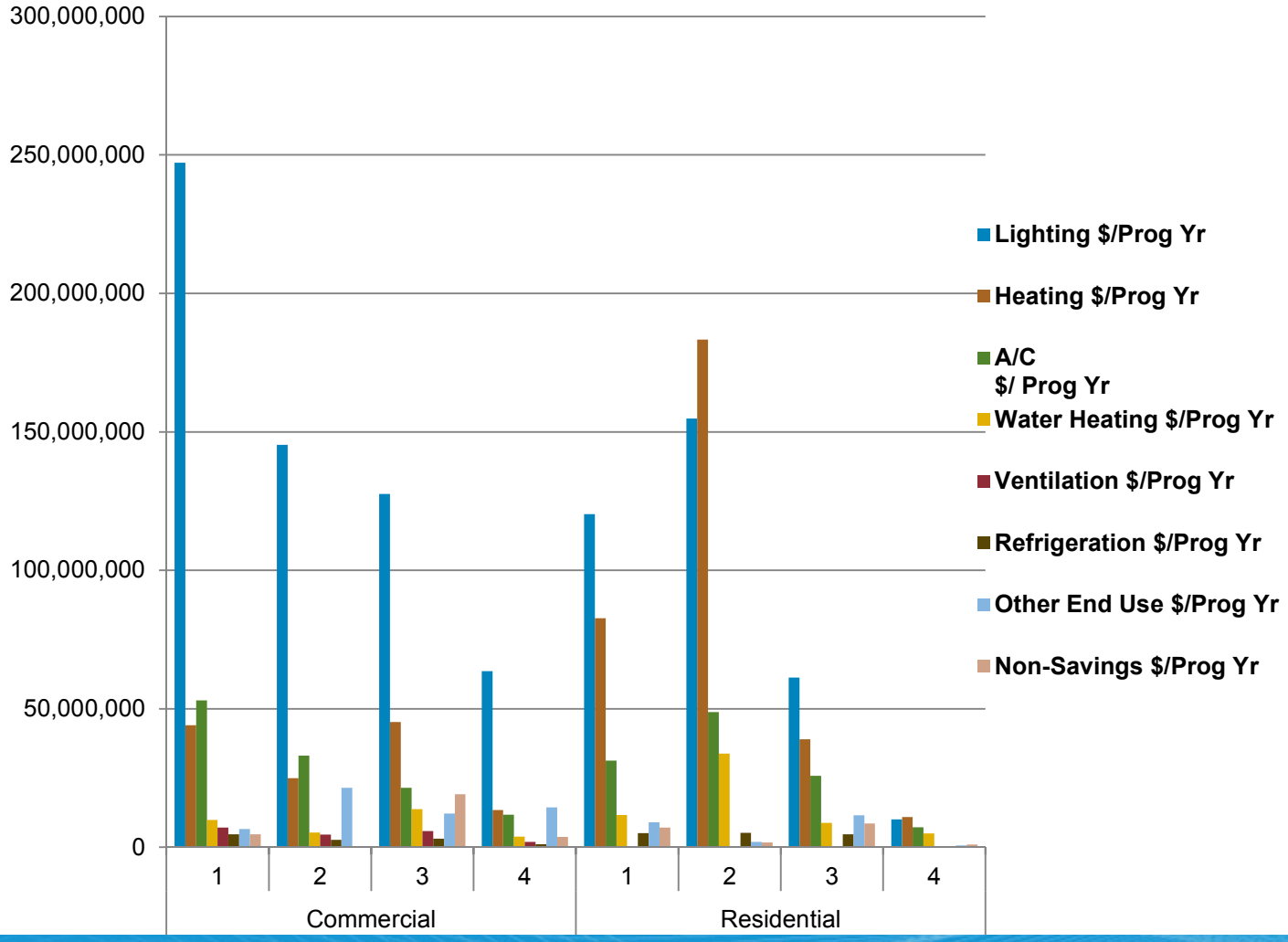
- Lazy User Theory. Consumers experience significant costs from the decision process itself and seek to minimize the disruptions from choice and transitions. Can be represented with lag variables and 'sticky' algorithms that favor current demand patterns over new ones.

- Generalized Bass Diffusion. Implements model of market transformation from technology (computing, telecoms) rich market analysis. Similar to current hurdle rate structure but using more abstract set of market uptake preferences (early adopters, mass market phases, laggards).

Current EIA work on demand specifications

- New regional energy efficiency 'investment portfolios' that allow NEMS to represent changing levels of activity
- Associates energy efficiency spending with specific sets of end uses and technologies over time
- Based on nationwide study of program activity intended to support regional aggregate representation
- To be used in current analysis of regulatory actions, and in future NEMS analysis including Annual Energy Outlook

EE program portfolios by Census Division



For more information

- Behavioral economics report:
  - http://www.eia.gov/analysis/studies/demand/economicbehavior/pdf/behavioraleconomics.pdf
- Behavioral economics workshop proceedings:
  - http://www.eia.gov/forecasts/aeo/workinggroup/buildings/workshop/behavior/?src=Consumption-b1
- Evaluation, measurement and verification report database:
  - http://www.eia.gov/efficiency/programs/inventory/