Projections of Industrial Energy Use: Does the Modeling Framework Make a Difference?

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Outline of Today's Discussion

- Describe our research objectives
- Describe the two models
- Explain both the similarities and differences between the two models
- Briefly discuss previous comparison efforts between CIMS and MARKAL
- Describe a typical industry and contrast it with the characterization in NEMS
- Provide a status report on this work in progress

Research Objectives

- Understand how model structure affects prediction of energy consumption in the industrial sector of the US.
- Identification of differences in market penetration of new technologies as a result of market share algorithms and technology choice criteria.
- Determination of which parameters have the most influence on model behavior for future research and refinement.
- Evaluation of how much the inclusion of price response in each framework affects the results.
- Simulation of the models under the same assumptions about growth in output, energy prices, and other exogenous economic factors.
- Evaluation of industrial technology policies with two different frameworks, and to determine if different conclusions may be drawn purely as a result of model structure.

The Two Models

- By name: CIMS-US and LA US-MARKAL
- CIMS-US is derived from the CIMS model maintained by Mark Jaccard and John Nyboer at Simon Fraser University in British Columbia, Canada.
- LA US-MARKAL is a MARKAL model of the US developed by Lorna Greening from Los Alamos, NM.
- Both of these are “bottom-up” models with explicit technology representation, and include all demands for energy services and sources of supply.

CIMS-US

- CIMS is an engineering-economic model of the U.S. economy based on a similar model developed for the Canadian economy by the Energy and Materials Research Group at SFU.
- This model is based on a version of ISTUM developed in the mid-1980s by PNNL for DOE.
- An earlier version of this model has been used to examine technology penetration under the title ITEMS: Industrial Technology and Energy Modeling System.

CIMS-US Structure

- In addition to the industrial sector included in ITEMS, CIMS also includes the other end-use sectors:
  - Commercial,
  - Residential, and
  - Transportation; and
- Energy extraction and conversion sectors:
  - coal mining,
  - oil and gas extraction,
  - petroleum refining and
  - electricity generation.

CIMS-US Structure (continued)

- There is also a macroeconomic link, that allows both energy supply and demand to respond to price signals.
- Price elasticities are the basis for these feedbacks.
- The model also allows for export and import of energy, which is one of the major linkages between the Canadian model and the U.S. model.
- The purpose of developing the U.S. model is to simulate the two countries together, to see what energy policies might help to reduce CO_2.

LA US-MARKAL

- Expanded technology choice set of over 4500 technologies which currently makes it the most detailed MARKAL model implemented for the US.
- Expanded set of resources including conventional (e.g., coal, oil,), renewables (e.g., wind, solar, MSW), and unconventional (e.g., methane hydrates, shale oil).
- Sectoral energy consumption representations include:
  - Commercial building (e.g., HVAC and lighting), and commercial end-uses such as refrigeration, office services, and similar activities.
  - Residential building consumption (e.g., HVAC and lighting), and end-uses such as refrigeration, cooking, and hot water heating.
  - Transportation for personal use (LDVs, SUVs, alternative fueled vehicles); freight haulage; and mass transit.
  - Industrial disaggregated into ten sectors.
- Use of materials in industrial sectors and nuclear fuel cycle.

LA US-MARKAL (continued)

- Expanded depiction of electricity generation capturing potential interactions between centrally dispatched generation and distributed generation.
- Each end-use sector has a sector-specific electricity and heat grid allowing for price competition between DG and central generation.
  - DG is treated as the 'marginal source
  - Aggregation contracts allow for inter-sectoral trades via the main grid.
- Complete nuclear fuel cycle including spent nuclear fuel disposal and reprocessing; the nuclear fuel cycle has been extended to 'advanced nuclear technologies.'
- Nine different emissions types (CO_2, SO_2, NO_x, N_2O, CO, VOC, CH_4, particulates, and mercury) tracked through the economy.

Similarities in the Models

- Both MARKAL and CIMS use the same set of industrial technology data of well over 2400 technologies.
- Both models use a 'process engineering' approach to describe the industrial sector, and both use physical units of output. This approach has the following advantages:
  - This specification results in a more realistic depiction of the derived demand for industrial energy.
  - More points where industrial energy consumption is reduced by technological improvements and the interactions between different technologies are captured.
  - Both platforms can be readily used to test for the effects of increases in the energy efficiency of specific industrial technologies, new technologies, or process improvements.
  - Use of physical units for output provides a ready linkage to other economic frameworks.
  - Endogenous estimates of motor drive and similar auxiliary energy services can be generated.

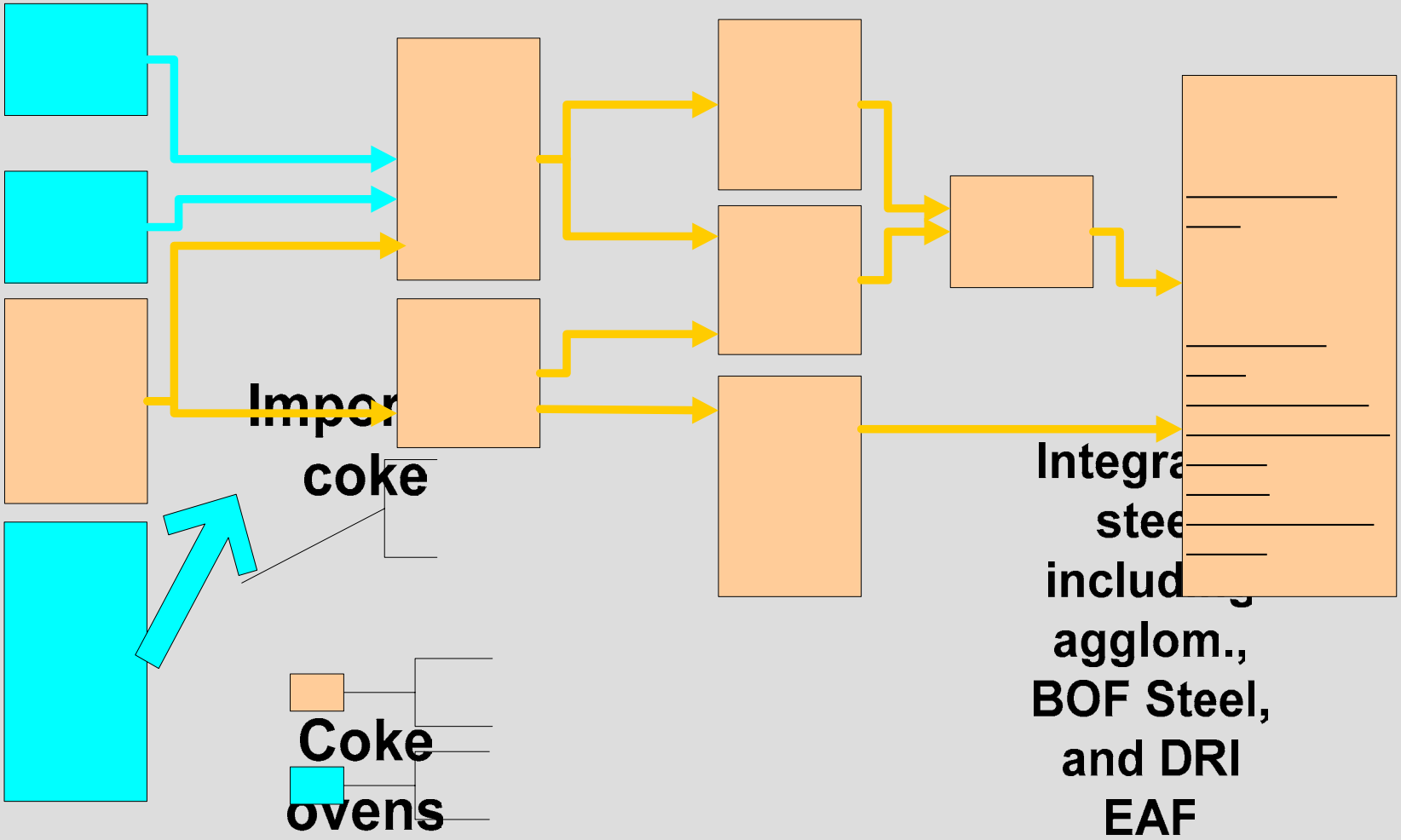
General Differences between CIMS and MARKAL

- MARKAL is an optimization framework while CIMS is a behavioral simulation framework.
- Market shares in MARKAL must be exogenously defined while in CIMS market shares are a probabilistic function of financial costs and other preferences.
- MARKAL generates a 'global solution' that minimizes the objective function subject to constraints; CIMS attempts to reflect bounded rationality of decision-making.
- MARKAL uses marginal costs for prices; CIMS uses average production costs for prices.

Previous Comparison Efforts

- CIMS and MARKAL have been previously compared in Canada.
  - Jaccard, M.A., et al. 2003. "Methodological contrasts in costing greenhouse gas abatement policies: Optimization and simulation modeling of micro-economic effects in Canada." *European Journal of Operational Research*, 145: 148-165.
  - Full results for both Canadian MARKAL and CIMS on: http://www.nccp.ca/NCCP/national_process/issues/analysis)e.html
- For this work, the price response in both models was disconnected.
- Using a "fixed output hypothesis," costs of meeting Kyoto were 6% greater from CIMS than MARKAL.
- CIMS indicated a 3% GDP impact, while MARKAL indicated less than 1%.

Process Depiction: Example Iron and Steel Sector



Comparison of CIMS/LA US-MARKAL Detail to NEMS: The Steel Industry

NEMS (EIA, 2005)

- 'Unit energy consumption' per unit of throughput at a process step derived from MECS.
- No technologies explicitly defined.
- Technological change defined by application of a productivity factor.

CIMS/LA US-MARKAL

- **Technologies explicitly characterized.**
- **Example detail: Steel**
  Integrated—12 BOF technologies
  Minimills—5 EAF technologies
  Casting—16 ingot, continuous, and thin slab casting technologies
  Reheating fur.—8 technologies
- **Technological change defined by choices made in technology set on basis of first costs, fixed and variable costs.**

Status

- Both models are currently simulating, but results available for only one industry
- Expectation is that we will be comparing results toward the end of the year
- Expect to have a paper for distribution and review early next year.

Questions?