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.
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.
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 (\(\text{CO}_2, \text{SO}_2, \text{NO}_x, \text{N}_2\text{O}, \text{CO}, \text{VOC}, \text{CH}_4, \text{particulates, and mercury}\)) tracked through the economy.
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.

- 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

Materials such as iron ore, direct reduction iron (DRI), and scrap are processed in the ironmaking and steelmaking segments. The ironmaking segment can be divided into two main processes: the basic oxygen furnace (BOF) process and the electric arc furnace (EAF) process. The BOF process typically includes the use of iron ore, direct reduction iron, and scrap as raw materials, while the EAF process is mainly fed with scrap.

The steelmaking segment includes the continuous casting process, which produces steel in the form of slabs, billets, and rounds. These steel slabs are then rolled into various shapes, such as beams, bars, and plates, in the rolling mill segment.
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.
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?