International Resources Group

Integrated E^3 Systems Modeling – Demystifying MARKAL/TIMES

What is the purpose of TIMES?

- To provide a framework for “what if” evaluation the mid-to-long-term evolution of an energy system, from a least-cost perspective
- To identify the technologies that are to play key roles in this evolution
- To quantify the ancillary implications of the policies and programs that shape this evolution

What is IRG's Role?

- To provide advisory and consulting services for the development, application, interpretation and transfer of the model for a wide range of government, NGO, university, donor and private sector clients
- To serve as the ETSAP Primary Systems coordinator overseeing the ongoing development of the modeling platform, and support its use around the world
- To "push the envelop" in terms of the capabilities and capacity of the MARKAL/TIMES modeling

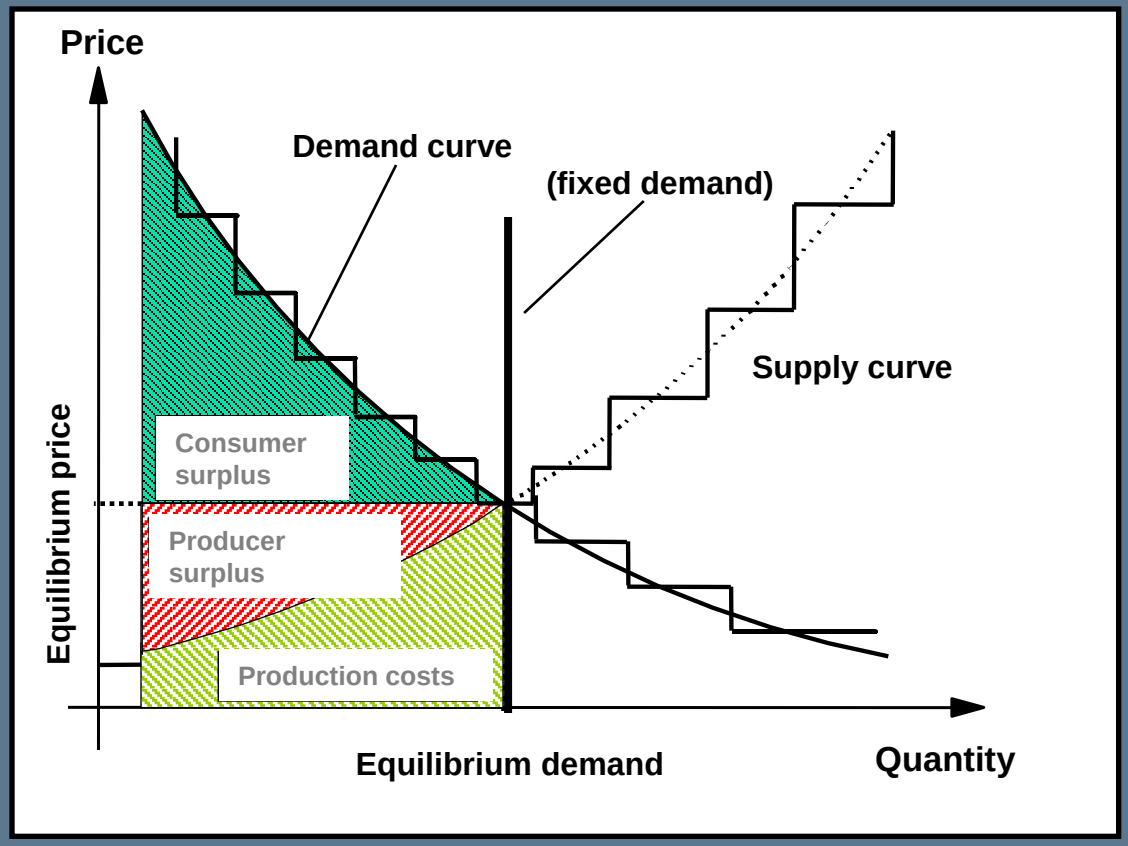
Who is using MARKAL/TIMES and for what?

- **Globally: IEA, EIA, ETSAP, EFDA**
- **Regionally: European Community, EPA-ORD, BNL, NESCAUM, China ERI, ASEAN, SEE**
- **Nationally: UK DTI/ERC, US BNL/EPA-ORD, numerous EU countries (Germany, France, Italy, Spain, Switzerland, Denmark, Norway, Sweden, Belgium, etc.), Russia, many developing countries (e.g., China, India, South Africa, APEC, Colombia, etc.)**
- **Other: several states (e.g., CA, CO, MA, NJ, OH, TX), NYC (and CUNY), several European cities (e.g., Geneva, Torino, etc)**

Model Characteristics

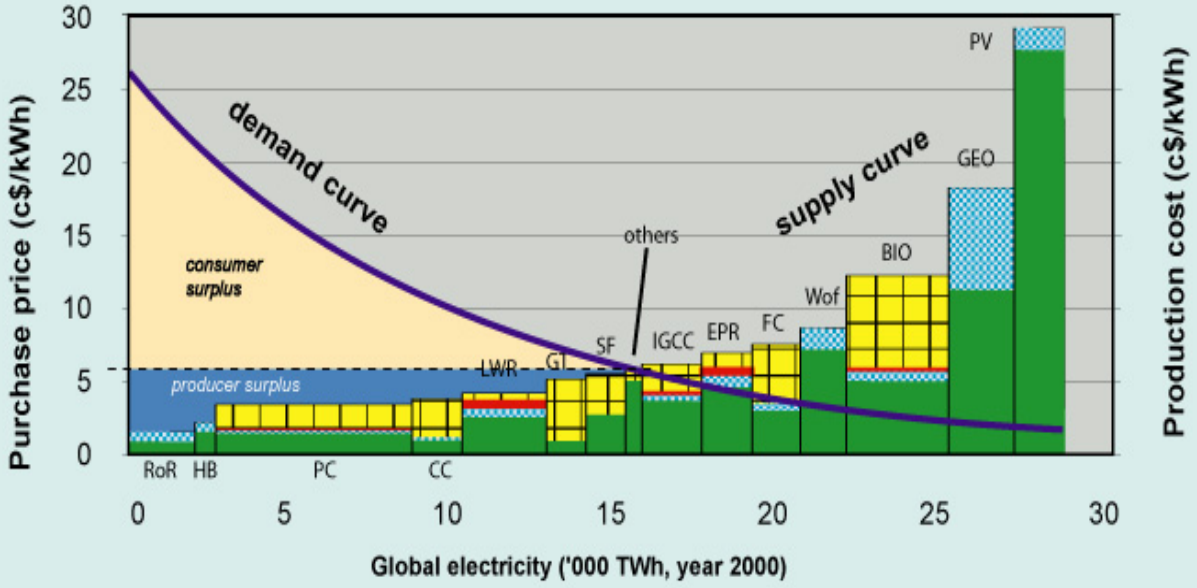
- **Evaluates all options within context of entire energy / materials system by:**
  - **balancing all supply/demand requirements**
  - **ensuring proper process/operation**
  - **monitoring in detail each process's capital stock turnover**
  - **adhering to user defined environmental & policy restrictions.**
- **Computes an equilibrium on energy markets that takes into account impact of policies on:**
  - **energy and product prices**
  - **technological development**
  - **energy security (trade)**
  - **attaining environmental goals**
  - **consumer behavior (e.g., miles driven, warming/cooling homes)**
  - **industrial output and profitability.**

Producer/Consumer Equilibrium and Elastic Demands



Courtesy IER-Stuttgart

Producer/Consumer Equilibrium per Commodity w/ Technology Detail



Power plants

RoR = run of the river
HB = hydro basin
PC = pulverized coal
CC = combined cycle
LWR = existing nuclear
GT = gas turbine
SF = steam fossil
others existing
IGCC = int. coal GCC
EPR = new nuclear
FC = fuel cells
Wof = wind offshore
BIO = biomass steam
GEO = geo hot dry
PV = photovoltaic

Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

Courtesy GianCarlo Tosato

How does TIMES differ from other energy models like NEMS?

- Employs least-cost optimization in a fully integrated modeling framework
- Open and transparent (source code and data assumptions)
- Data driven, so more a model generator conforming to a set of well-defined rules than a program or specific model
- No iteration between modules (unless linked to an economic model)
- Rapid response times (though very large multi-region models may take an hour)
- Long-standing international commitment to the ongoing development and use of the model
- A robust user support system “shell” overseeing all aspects of working with the model

What are the key inputs?

- Characterization of the current stock of existing technologies
- Resource supply (step) curves, and cumulative resource limits
- The characterization of future technology options
  - Fuels in/out, efficiency, availability, technical life duration
  - Investment, fixed and variable O&M costs, and “hurdle” rates
  - Emission rates
  - Limits on technical potential
  - Performance degradation (e.g., efficiency, maintenance costs)
- Demand breakdown by end-use
  - Demand for useful energy
  - Own price (and income) elasticities
  - “Simplified” load curve
- Discount rate, reserve margin

What are the key Outputs?

- Total Discount System Cost
- Resources levels and marginal costs, if constrained
- Technology
  - Level of total installed capacity
  - Annual investments in new capacity and expenditure
  - Annual fixed and variable operating and fuel costs
  - Annual and season/time-of-day (for power plants) utilization
  - Marginal cost, if constrained
- Energy consumed by each technology (sector), and marginal price (by season/time-of-day for electricity)
- Demand marginal costs and change in levels, if using elastic MARKAL (or MACRO)
- Emission level by resource/sector/technology for each period, and marginal costs, if limited

How does the model's analysis work?

- Encompasses ***entire energy system*** from resource extraction through to end-use as represented by a Reference Energy System (RES) network, and
- employs least-cost ***optimization***
- looking to ***maximize producer/consumer surplus*** by
- identifying the most ***cost-effective*** pattern of resource use and technology deployment over time under varying constraints and alternate futures.

What types of policy questions is it good at answering?

- Impacts of technology development programs
- Mandatory micro-measures in each sector: building code, building retrofit programs, modal-split incentives in freight and passenger transports, energy efficiency programs, etc. vehicle standards
- Energy taxes, investment subsidies (e.g., green and white certificates, clean/efficient technologies)
- Renewable portfolio or performance standards
- Energy security evaluation (oil/gas/nuclear fuel imports energy options evaluation)
- Emission targets and mechanisms (e.g., cap and trade, taxes, sector intensity)
- Merits of education, information dissemination
- Impact of social constraints, e.g. nuclear

What types of policy questions is it not so good at answering?

- Preparing energy, technology, emissions, economic forecasts (exception: SAGE variant at US-EIA)
- Representing and studying the behaviour of monopolistic markets
- Evaluating the amount of available fossil or renewable reserves and ultimate resources
- Analysing the effects of non co-operative games (exception: the Nash equilibrium version at GERAD, Canada)
- Studying the global climate and its effects (exception: the climate equations have been internalised in TIMES)
- Studying the social behaviour towards energy options, in term of consumer preference or acceptability of an option

Suggestions on how to draw valid policy conclusions

- Take advantage of scenario capabilities to conduct sensitivity analysis
- Understand its strengths and weaknesses
- Use tools and techniques to explore the solutions space (e.g., EPA-ORD, LLNL, others)
- Use it as a complimentary framework to provide technology insight (e.g., ETP with WEO, UK White Paper with Oxford econometric model)
- Have lunch with a TIMES modeler ☺