EPA
United States
Environmental Protection
Agency

Energy Modeling with MARKAL

MARKAL is a data-intensive, technology-rich, energy systems economic optimization model that consists of two parts:

- an energy-economic optimization framework, and
- a large database that contains the structure and attributes of the energy system being modeled.

Energy system details represented in MARKAL include primary energy resource supplies, energy conversion technologies, end-use demands, and the technology options that can be used to satisfy the specified demands. An illustrative diagram representing simplified energy flows in MARKAL is shown in Figure 1.

MARKAL uses linear optimization techniques to identify the least-cost way to satisfy the specified demands, subject to user-imposed constraints such as emissions limits. Outputs of the model include the optimal

SUMMARY

NRMRL has developed a first-of-a-kind, nine-region MARKAL model of the U.S. that can be employed by federal and regional decision-makers to explore future scenarios of energy system development and the associated emissions.

technological mix at specified intervals in the future, the total system cost, criteria and greenhouse gas emissions, and energy commodity prices. MARKAL assumes rational decision-making, with perfect information and perfect foresight, and optimizes over an entire multi-year modeling period simultaneously. The results represent the optimal technological mix over time from a societal standpoint. Because there is a high degree of uncertainty regarding the specification of future technologies and fuel prices, extensive scenario analysis is employed to map the economic landscape and search for technological tipping points.

National and Regional Databases
The MARKAL modeling framework is maintained and updated by a large international consortium, but the underlying energy database is developed by each user group. NRMRL has developed both a national and a nine-region U.S.-specific energy database that characterize resources, technologies, and demands

Figure 1. Energy Flows in a Simplified Depiction of an Energy System
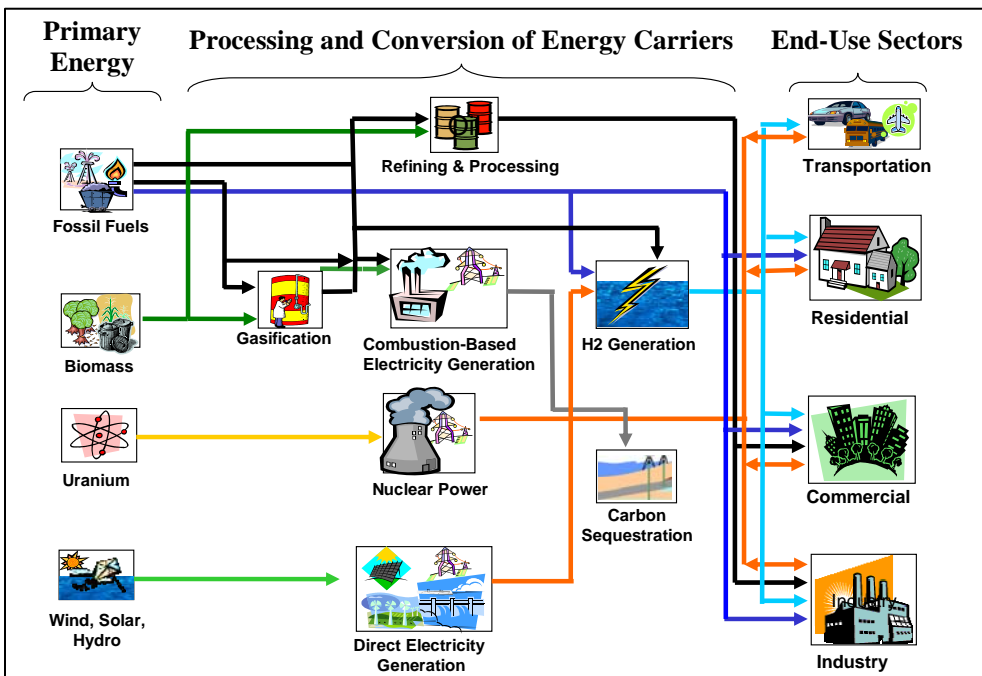
through 2050. The former, referred to as EPANMD (EPA National MARKAL Database) was developed first and represents the energy system aggregated to the national level.

Recognizing that future energy systems are likely to be region-specific, NRMRL has also developed a nine-region MARKAL database, the first of its kind, where each region represents a census division. The nine-region database, which is currently being calibrated, will provide refined scenarios that take into account regional variation in resource availability, transportation costs, and end-use demands. The regional model also allows trading of primary energy supplies, electricity, refined petroleum products, and other fuels across regions.

Capabilities

NRMRL/APPCD researchers are using the MARKAL energy system model to estimate future-year technology penetrations and the associated emissions. With five economic sectors (commercial, residential, industrial, electric, and transport) represented across nine regions, the EPA nine-region MARKAL database and model will provide federal and regional decision-makers with a valuable tool to explore a variety of future energy scenarios such as:

- How might a federal renewable portfolio standard be met across regions?
- Will the development of a hydrogen economy decrease or increase air pollution and greenhouse gas emissions? How might hydrogen affect the price of other commodities?
- What might be the role of biofuels and biopower in the transportation, power, and industrial sectors? How might different sectors compete for limited biomass resources?
- How do regions differ in their capacity to produce, transport and use biomass feedstocks?
- What energy technologies could be deployed over the next half-century to meet a low carbon trajectory in the U.S.?
- What are the potential emission consequences of technologies which may be deployed over the next half-century?

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Integrated Systems Analysis Workgroup

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Recent Publications

Decarolis, Shay & Vijay (2007). "The potential mid-term role of nuclear power in the United States: A scenario analysis using MARKAL." In Energy Security, Climate Change and Sustainable Development (New Delhi: Anamaya Publishers)

Johnson, DeCarolis, Shay, Loughlin, Gage & Vijay (2006). MARKAL scenario analysis of technology options for the electric sector: The impact on air quality. EPA/600/R-06/114.

Shay, Yeh, DeCarolis, Loughlin, Gage, & Wright (2006). "MARKAL database: Database documentation." EPA/600/R-06/057.