MARKAL Model Helps Identify Environmentally Friendly Energy Strategies

What does the future hold for the production and use of energy, and how will our energy choices impact air quality, climate change, and water demands? Models are providing us information to make better decisions about how to meet our energy needs, sustain and grow our economy, and protect the environment.

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The MARKet ALlocation (MARKAL) energy system optimization model is being used by U.S. Environmental Protection Agency (EPA) researchers to peer 30 to 40 years into the future under possible scenarios and study different options for the nation’s energy system, which includes the electric power generation, industry, transportation, and buildings sectors. The researchers developed a database specific to the U.S. energy system for use with MARKAL. The database allows the model to be applied to explore energy scenarios stretching from 2005 to 2055.

“MARKAL is an energy modeling framework,” says Rebecca Dodder, a physical scientist at EPA.
on the MARKAL research team. “It’s a computer system that allows us to identify cost-effective and environmentally-friendly energy strategies.”

Dodder and other EPA researchers recently employed MARKAL to understand how energy-related water demands may change over the next several decades. Their analysis also considered how climate-induced water shortages could affect electricity production choices. Electricity generation accounts for about 45% of U.S. water withdrawals, making it the largest demand on the nation’s fresh water supply.

EPA researchers are also using MARKAL to understand the impacts of energy choices on the emissions of air pollutants and greenhouse gases such as carbon dioxide (CO₂). The energy system is the primary anthropogenic source of these pollutants in the United States.

“With MARKAL, we can identify future air quality management challenges and test cost-effective management strategies, all in a virtual environment,” says Dan Loughlin, an EPA researcher on the MARKAL research team.

The original MARKAL software program was developed by the U.S. Department of Energy’s (DOE) Brookhaven National Laboratory in response to the Oil Crisis of the 1970s. The International Energy Agency (http://www.iea-etsap.org/web/Markal.asp) oversees its continued development, and the model is now used worldwide by 77 institutions in 37 countries.

The EPA energy system database is being shared with several dozen leading universities, and has been used by researchers and analysts at DOE’s National Energy Technology Laboratory and Oak Ridge National Laboratory, MITRE Corporation, the Northeast States for Coordinated Air Use Management, the Natural Resources Defense Council, and the World Resources Institute.

EPA researcher Carol Lenox, who is on the MARKAL research team, says, “We developed the database with the goals that it be open, transparent and accessible to others outside the agency. As a result, the database has been used in a wide array of research contexts and has been the starting point for a number of other energy system databases, including ones built for the states of Ohio and Indiana, as well as a multi-state model of New England.”

So How Does It Work?

EPA researchers have added thousands of data points to the MARKAL database. These include estimates of current and future energy supplies, demands, and technologies. Energy supplies include coal, natural gas, and petroleum, as well as renewable energies such as wind, solar, geothermal, and hydro power. Energy demands include lighting, space heating and cooling, and passenger travel. In addition to currently available technologies, those that are not yet widely available commercially also are included, such as grid-scale batteries for storing renewable power and hydrogen fuel cell vehicles.

In conducting an analysis with MARKAL, EPA researchers may make incremental changes to the model’s inputs to explore how technology and fuel...
EPA researchers are also using MARKAL to understand the impacts of energy choices on the emissions of air pollutants and greenhouse gases. Dodder is trying to understand better the energy-water connection or nexus for the U.S. electricity sector. One question is what happens to water demand with a switch to more nuclear power or carbon capture and storage? The answer: in many parts of the country an increase in consumptive demand for water can occur. The research on water impacts was published August 2014 in an article in *Current Opinion in Chemical Engineering*, titled “A review of water use in the U.S. electric power sector: insights from systems-level perspectives” (http://dx.doi.org/10.1016/j.coche.2014.03.004).

“There are tradeoffs between water consumption and CO₂ reduction,” Dodder said. “We asked whether we would be able to meet deep CO₂ reductions and tight water consumption constraints simultaneously, and we found that doing so in all regions could be highly challenging.”

Dodder says that a change in technology could easily alter this scenario. For example, if concentrated solar power in Southwestern United States adopts new methods called dry cooling, water needs would shift downward over time.

On the air quality side, Loughlin is using MARKAL to investigate how air quality management strategies have affected greenhouse gas (GHG) emissions and how possible reduction strategies could lead to cleaner air.

“Instead of tackling various air pollutants and GHGs separately, MARKAL is allowing us to find pathways to meet air quality and GHG mitigation goals together, taking advantage of synergies,” Loughlin says.

The work is published in the article titled, “GLIMPSE: A Rapid Decision Framework for Energy and Environmental Policy,” in the journal *Environmental Science and Technology* in 2013 (http://pubs.acs.org/doi/abs/10.1021/es402283j). EPA researcher Ozge Kaplan is taking the EPA’s MARKAL modeling in another direction. She is working to apply MARKAL at the community scale, helping communities to evaluate how best to provide energy for residents, commerce, and industry that is economically viable while at the same time minimizes air pollution and water needs.

Kaplan says, “Our MARKAL work has the potential to make a significant difference through addressing communities’ questions related to energy, environment, and climate.”

I’ve enjoyed *EM*, both as a reader and a contributor. As a reader, I’ve found the content timely and useful, allowing me to remain informed about issues that are related to my area of focus. As a contributor, I’ve found the editorial stall excellent and dedicated to producing a high-quality publication. In short, *EM* allows me to learn from my colleagues and share what I know with my colleagues. In my opinion, you can’t go wrong: Read it. Write for it. Or do both.

—David L. Elam, Jr., regular *EM* contributor, “PM File” column

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