MARKAL

INTEGRATED ENERGY SYSTEMS PLANNING

MARKAL/TIMES is an integrated energy systems modeling platform that can be tailored to analyze energy, economic and environmental issues at the global, national and municipal level over several decades. This set of software tools provides a framework for exploring, evaluating and quantifying alternative futures and the roles that various policy options may have on technology and resource choices.

MARKAL is the acronym for MARKet Allocation while TIMES — which is the next generation version of MARKAL — stands for The Integrated MARKAL/EFOM System.

International Resources Group (IRG) staff were integral to the development of the MARKAL/TIMES modeling platform under the support of the International Energy Agency (IEA) and the ETSAP[1] community in response to the increased demand for a way to accurately model and measure the thousands of variables that guide governments and commercial enterprises in:

- Identifying least-cost energy systems and investment strategies[2]
- Identifying cost-effective responses to restrictions on environmental emissions and wastes under conditions of sustained development
- Evaluating new energy markets, technologies and priorities for R&D
- Managing energy security
- Evaluating the effects of regulations, taxes, and subsidies
- Preparing UNFCCC assessments and National Communication Action Plans[3,4,5]
- Evaluating of options for a low-carbon future[6,7]
- Examining the transition of rural energy away from traditional, highly polluting, energy forms[8]
- Determining the costs and benefits of Renewable Portfolio Standards[9]
- Developing integrated local energy and waste management planning
- Determining Greenhouse Gas (GHG) emission baselines, evaluating mitigation projects and estimating the value of carbon rights[10,11]
- Determining the value of regional and international cooperation[12,13]

MARKAL/TIMES strength is its technology richness, transparent architecture (with respect to both data and well-understood methodology), and usability owing to robust analyst support systems. It is a full-sector model, meaning that it encompasses not just power generation but also upstream fuel production and all forms of energy consumption in all demand sectors of an economy. MARKAL/TIMES models are constructed for specific geographical boundaries that can range from global, multi-region models, to single and multi-region national models as well as sub-regional models down to the municipal and even village level.

How it Works

The MARKAL/TIMES model accepts industrial, commercial, residential, and transportation demands for energy services over the next several decades, and determines where the sources of energy will originate – whether domestic or imported – based on the available technologies that transform primary

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[1] *ETSAP retains the Intellectual Property Rights to MARKAL/TIMES. Source: the IEA Energy Technology Systems Analysis Programme www.estap.org/markal/ma*

[2] *EC New Energy Externalities Development for Sustainability (NEEDS), www.needs-project.org. Follow-on projects include projects aims to evaluate the Renewable Energy Standards directives for the EU27 (http://www.res2020.eu/, and Risk of Energy Availability) and Common Corridors for Europe Supply Security (EACCESS), which is a techno-economic + environmental evaluation of global energy supply options for the EU in the context of long term sustainability and energy security.*

[3] *Second National Communication of Italy for the United Nation Framework Convention on Climate Change, G.C. Tosato, M. Contaldi, and D. Gaudioso, prepared by ENEA for the Ministry of the Environment, 1999. Available from the Italian Ministry of the Environment, SIAR, Via Cristoforo Colombo 44, I-00100 Roma; also www.unfccc.de.*

[4] *The Third National Communication of the Republic of Latvia Under the UNFCCC, Ministry of Environment Protection and Regional Development, 2001, http://www.varam.gov.lv/vide/publik/Epub.htm.*

[5] *Loulou, R., et al, Integrated Analysis of Options for GHG Emission Reduction with MARKAL, Prepared for the Canadian National Climate Change Implementation Process, June 3, 2000.*

[6] *Options for a Low Carbon – Phase 2, prepared by AEA Technology Plc. for the UK Department of Trade and Industry, 2002, http://www.dti.gov.uk/energy/whitepaper/phase2.pdf.*

[7] *Final Report on DTI-DEFRA Scenarios and Sensitivities using the UK MARKAL and MARKAL-Macro Energy System Models, 2007, http://www.ukerc.ac.uk/content/view/142/112.*

[8] *An Energy Model for a Low Income Rural African Village, Program on Energy and Sustainable Development, Stanford University, June 2003, http://iis-db.stanford.edu/viewpub.lhtml?pid=20219&cntr=cesp*

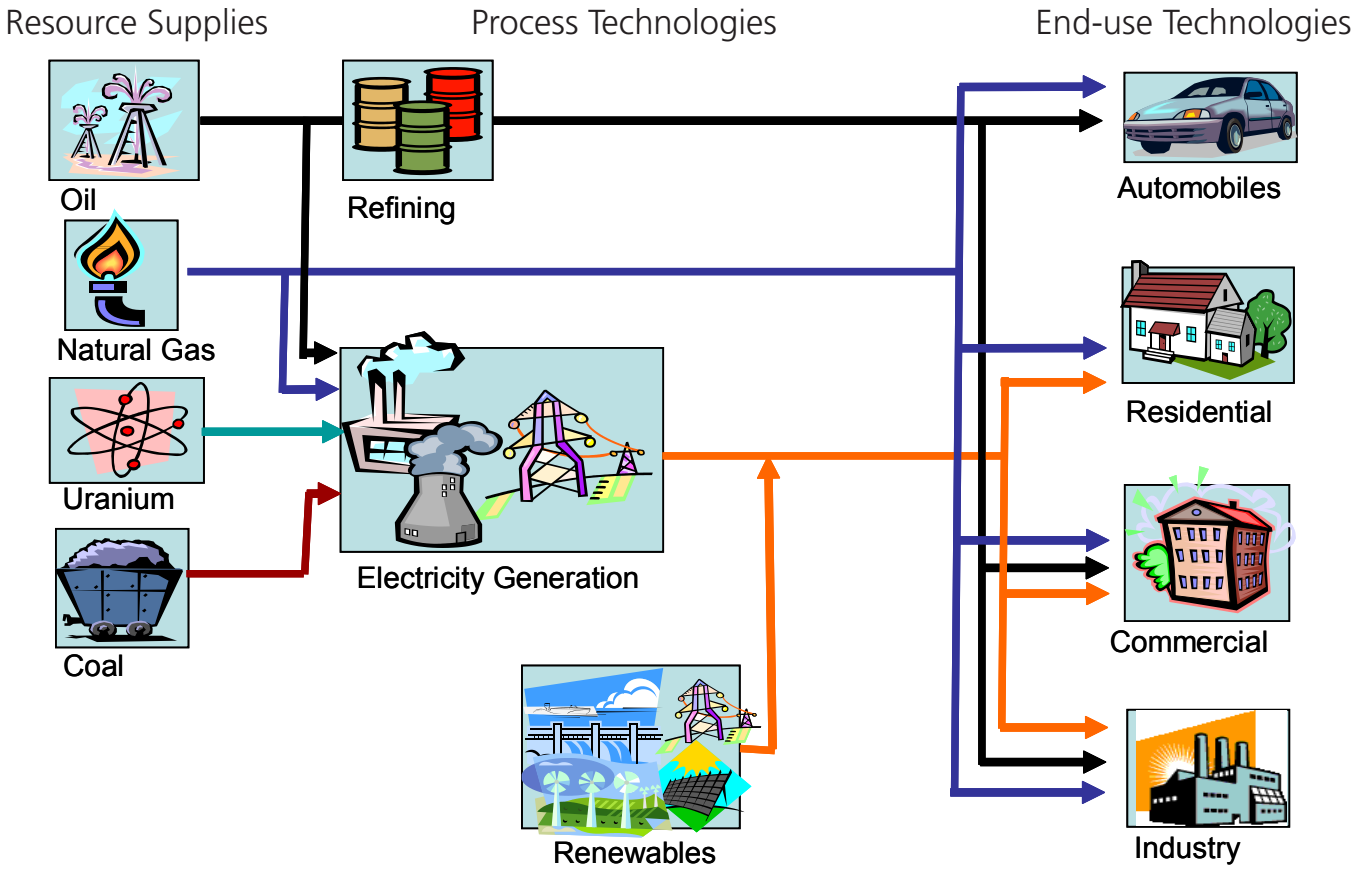
[9] *Including New and Renewable Technologies in Economy-level Energy Models, Asia-Pacific Economic Cooperation, September 2002, APEC#202-RE-01.011, ISBN: 0-9726293-0-0.*

[10] *Models to Asses the Implications of the Kyoto Protocol on the Energy System and Economy of Colombia, Cadena Angela, HEC, School of Economy and Social Sciences, University of Geneva, Switzerland, 2000.*

[11] *USAID providing support to Panama, El Salvador and Honduras under CONCAUSA Plan of Action on Climate Change; and Bolivia to study the economic impact of reforestation for GHG mitigation.*

[12] *Northeast States for Coordinated Air Use Management, New England MARKAL Model, ongoing, http://www.nescaum.org/projects/ne-markal/index.html.*

[13] *"Energy Policy and Systems Analysis Project," 8-country (3.5 year) capability building undertaking sponsored by USAID under Phase III of the ASEAN-Australia Economic Cooperation Programme.*



energy into final energy that is used by end-use devices to meet the demands for energy services. The components are tied together by means of a Reference Energy System (RES), as depicted above, which establishes the network of energy flows and technology options encompassing the energy system. The characteristics of each technology (resource supply, process, conversion and end-use) include the investment cost, operating and maintenance costs, service life, efficiency, availability and emissions.

The MARKAL/TIMES model then simultaneously identifies the least-cost mix of energy carriers and existing and new technologies that will satisfy the energy service demands and meet all the constraints imposed on the energy system. Common constraints include limitations on the rate of fuel switching or the penetration of new technologies, caps on various emissions (SO_2, NO_X, CO_2, mercury, etc.), minimum requirements for renewable energy, etc.

MARKAL/TIMES models also have the ability to allow the actual energy service demands to respond to price pressures by means of own-price elasticities. They also allow for learning-based cost reductions as new technologies get taken-up by the energy system. In addition, MARKAL/TIMES models are used for tracking material flows, factoring in lumpy investments, and the development of hedging strategies by employing probability functions.

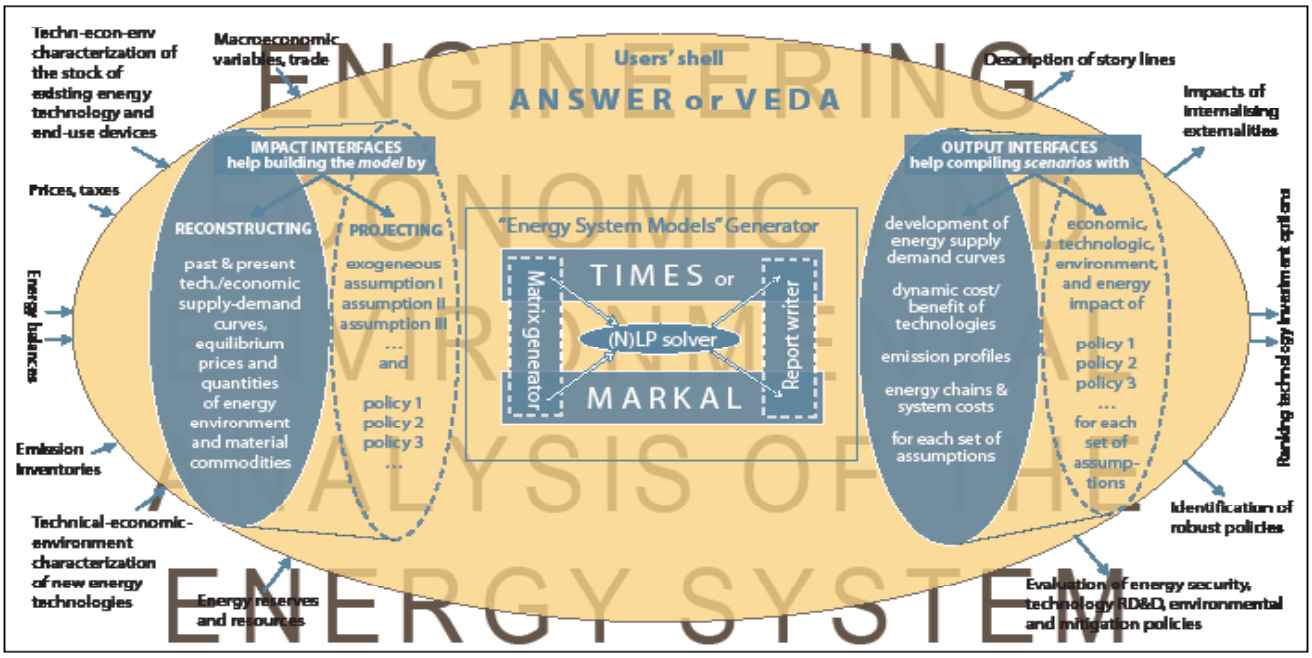
Once a model is established, its base year is calibrated to actual data from the energy system being modeled, and a Reference scenario is established that is often based on "official" projections that constitute a business-as-usual future. Then a series of Policy scenarios can be investigated with the model to explore their impact in comparison to the Reference scenario.

Policy scenarios that can be analyzed with the model include measures to improve energy security, cut emissions, promote energy efficiency, reduce new technology costs, impose a cap-and-trade program, institute incentives or impose taxes. The value of the model is that the impacts of these policy scenarios can be compared in terms of the different technologies used, the different fuels consumed, the change in energy system cost, emission levels, etc.

Another strength of the platform are the analyst support systems, or "shells", VEDA (The VErsitile Data Analyst) and ANSWER, which oversee all aspects of working with the model. These systems integrate with Excel spreadsheets to facilitate the assembly of the underlying data, provide facilities for filtering and viewing data, support graphing and RES diagramming, and enable submitting model runs and the management of the numerous scenarios required to conduct a full analysis.

Construction of a national MARKAL/TIMES model for a country can be completed within a couple of months, if the level of detail is not too complex, the data are readily available and a MARKAL/TIMES expert oversees the process. More complex MARKAL models may take up to one year to create and require an ongoing process to collect data and improve the model. A typical single region MARKAL/TIMES model runs in under a minute, while large multi-region models take 5-40 minutes, using current PC technology.

ETSAP Tools and Typical Applications



Source: The International Energy Agency (IEA) Energy Technology Systems Analysis Programme (ETSAP)

Acronyms:
MARKAL = Market Allocation Model
TIMES = The Integrated MARKAL – EFOM System
LP = Linear Programming
NLP = Non-Linear Programming
VEDA = Versatile Data Analyst
RD&D = Research, Development & Deployment

IRG MARKAL/TIMES Activity Highlights

- IRG developed a national model for the US Environmental Protection Agency (USEPA), which has been used to perform a variety of studies in collaboration with the USEPA regarding transportation sector impacts on air pollution and the introduction of new nuclear and hydrogen-based technologies. The current version of the model is being used by IRG on behalf of the Natural Resources Defense Council (NRDC) to analyze strategies for achieving deep CO_2 reductions in the US.
- IRG has developed a 12 state regional model of the US Northeast for the Northeast States for Coordinated Air Use Management (NESCAM). The model has provided NESCAUM a powerful tool to plan for its current policy goals and evaluate other programs that may be required to maintain and improve air quality in the region, to promote cleaner, more efficient energy use, and to foster energy security. The model encompasses the entire Northeast energy market from New England through New York to Pennsylvania, New Jersey and Maryland. Among other analyses, the model is being used to evaluate plans to implement a regional power sector cap and trade program for CO_2, as well as to explore all sector mitigation opportunities.
- In Southeast Europe, under funding from USAID, IRG has guided and supported national teams to assemble energy models for eight Balkan countries (five former Yugoslavia republics plus Albania, Bulgaria and Romania). Working with the various energy ministries and power companies in the region the project has built local capacity, developed the data, and created a consistent modeling framework within the region. The country models are currently being used to assess future trends in the demand for energy, analyze opportunities for improved end-use efficiency, and explore options for expanding natural gas markets. In the future, these regional models are expected to be used to examine the potential role of renewable energy technologies, to explore the benefits of creating a regional electricity grid, and to examine the costs of integration into the European Union (EU) internal energy market.
- On behalf of a major national oil company, IRG is currently engaged in the development of a national planning framework. The project will look to develop the initial model in close collaboration with our partner, conduct a series of sensitivity runs to assess strategies for meeting the future energy demand, and ultimately transfer the full-blown model to the national oil company for ongoing use.
- At the request of various institutions around the world IRG has conducted dozens of capacity building workshops in support of national planning activities in numerous countries. These undertakings have repeatedly resulted in the establishment of high caliber modeling teams able to support the analysis of government policies aimed at guiding the future evolution of their energy systems.

MARKAL/TIMES Activities Around the World

Worldwide, some 200 institutions in over 60 countries use MARKAL/TIMES, fostering informed decision-making for what are increasingly more energy and environmentally conscious societies. IRG has been a leader in capacity building working for the US Agency for International Development and directly for dozens of government and research institutions around the world.

In the global context the IEA, the US Energy Information Administration (EIA), and ETSAP have assembled models to facilitate bottom-up analysis of common problems from a global perspective for the first time. This depth and breadth of availability of the methodology, and its inherent fit as an ideal tool for examining greenhouse gas mitigation strategies, uniquely positions it to contribute to post-Kyoto dialogue from both sides of the table (developed and developing countries).

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