Volume 8, No. 1 June 2002

IEA OECD

ETSAP news

ANNEX VIII EXPLORING ENERGY TECHNOLOGY PERSPECTIVES

Integrating Top-Down and Bottom-Up Modeling Perspectives

ABARE organized a symposium during the May ETSAP meeting to provide interaction between ETSAP and energy researchers in Australia. Brief summaries of the presentations are given.

Robert Dixon, Deputy Assistant Secretary, U.S. Department of Energy. Climate change is a long-term, global issue that needs a national and international response. Two facets of the U.S. response are two climate change initiatives: one on technology and the other on research. These initiatives recognize the central role for technology in global climate issues, with the basic principle being "advancing science to reduce fundamental uncertainties." Based on global participation, including developing countries, the aim is to stabilize concentrations of GHGs. This has non-trivial implications for energy and requires a fundamental change in the energy system. Net emissions must eventually decline to virtually ZERO. This will require technology and policy in the near term (5 to 50 years), mid-term (30 to 100 years), and long-term (50 to 150 years).

Energy technologies that potentially play a major role in the mid- and long-terms are NOT significant components of the present energy system. To be ready to meet the long term needs, President Bush proposed five tasks: (1) evaluate technology research; (2) develop opportunities to enhance private/public partnerships; (3) demonstrate cutting edge technologies; (4) improve meaning and monitoring of GHG emissions; and (5) provide guidance to strengthen basic research. This is a research shift to more fundamental, higher risk activities with emphasis on fuel cells and hydrogen.

Steve Payne, General Manager, Greenhouse and Environment Policy Branch, DITR Ninety percent of Australian electric power comes from fossil fuel. DITR is working on carbon sinks and a greater range of abatement options. They are investigating the range of uncertainty.

Doug Hill Retires

Doug Hill was involved with ETSAP from the beginning. He was the U.S. technical representative for many years before becoming the editor and was a promoter of the model. Doug edited the ETSAP news for 12 years. We are sorry to lose him. Doug has recently been working with Columbia University on climate change issues and with the Marine Science Center at Stony Brook University on storm surge barriers to protect Manhattan Island. He is organizing a new effort to address heat stress in New York City, focusing on older, infirm, solitary, and low-income city residents.

In this issue

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Information on ETSAP, its activities and members is also provided on the Internet. The home page contains the latest news, general information on ETSAP, and links to: ETSAP member; ETSAP 'outreach' activities; description of the MARKAL model and its users; archives of new item; selected publications and the ETSAP Newsletter.

Quick Takes

Australia: Intelligent Energy Systems is doing MARKAL training in Thailand

Belgium is moving to TIMES exclusively.

Switzerland is looking at local damage from climate change.

Canada: MARKAL work is moving to the Natural Resources Desk. They are involved in a national climate change process, studying disaggregation of MARKAL by income groups, working with the National Institute of Sustainable Development, and with Environment Canada on criteria air pollution.

United States: Endogenous learning will be important. Sustainable buildings, residential buildings and freight transport are current issues. There is an effort to examine differences in income groups. Assistance to developing countries and CDM continues.

Using MARKAL-MACRO to analyze an R&D portfolio

An optimization model coupled with scenarios provides an approach to quantitatively assess the prospective *benefits of research and development (R&D) in a comprehensive and consistent manner. It focuses on a broad R&D portfolio, rather than a detailed examination of the impact of individual R&D projects, providing a "big picture."*

Richard Loulou, and Amit Kanudia, Canada

Requirements for detailed long-term energy-environmental analyses are the ability to represent detailed energy systems; multiple sectors, multiple technologies, and multiple regions. Also, these models must include capital turnover detail; trade of energy and materials; ability to generate prices endogenously, and the ability to model main economic indicators (production, consumption, employment, and interest rate). One must also be able to examine the main costs and benefits and the ability to model structural changes (e.g. technological adaptation and behavioral changes).

CGE models could theoretically include as much technological detail as needed. A limit arises, however because of algorithmic capabilities (Non-linear equations and inequations). Conversely, bottom-up models could theoretically compute aggregate consumption, GDP, and aggregate capital. Here, again, the limitation comes from technical considerations (non-linearity combined with large size). The solution is first to extend bottom-up models as far as possible without hitting technical limits, thus technical detail is preserved and second to supplement bottom up models with a macroeconomic model. The main output from a bottom-up model is a detailed schedule of investments and other expenditures, and of prices, by each sub-sector, at each time-period. Once precisely interpreted, these parameters are input into a macroeconomic model that calculates the impacts on disposable income, on consumption, on labor and wages, interest rate, inflation, etc. A key issue: is it necessary to feed macro results back into bottom-up model? Tentative answer: No. The approach (with no feedback to bottom-up) assumes that demands for energy intensive products and services are not significantly altered in the macroeconomic model (for instance the impacts on demands of income or of government budget are neglected) In other words, it is assumed that the price elasticities used in the bottom-up model capture most of the variability of energy intensive demands. There is some support for this thesis (Kram and Sheepper, 1994), but more experimentation is needed.

Vivek Tuipulé, Deputy Executive Director, ABARE

This was an introduction to modeling climate change policies using GTEM. GTEM is a CGE model of the world economy. It is multiregional, multisector , dynamic, and energy focused. It makes use of technology bundles. Greenhouse gases in the model include CO_2, CH_4 and N_2O.

Denis Holly-Burton, Domestic Energy Policy Branch, DITR

Energy in Australia is developed in a national agreed upon foundation between Federal and State government. Recent market reforms moved state-owned electric and gas to the private sector. There is now substantial competition across state borders, assuring consistency in energy standards. Major issues foreseen over the next 20 years are: world energy demand to grow 57%, Australia's energy system to grow 35-50%, investment demand, challenging environmental goals, and how to assure energy goals, energy security, and energy self sufficiency.

Philip D. Adams, Centre of Policy Studies, Monash University, Australia
The MMRF-Green model is a dynamic, multi-sector, multi-regional, top-down model of Australia, with enhanced capabilities for analysis of environmental policies. It is very detailed, distinguishing up to 45 industries, 50 commodities, 8 states/territories and 56 sub-state regions.

Using CGE models for detailed forecasting is a relatively unexplored area of research. They have been successful in using the MONASH model and MMRF-Green for this purpose. This suggests that this could become a rich field of research. They are currently including changes to the industrial classification to bring it into line with the current classification used by the Australian Bureau of Statistics, and updating to reflect a more recent year of historical observations. Other work involves better modeling of forestry sinks, agricultural emissions from non-combustion sources, and the incorporation of endogenous take-up of abatement technologies.

Some policies explored in the model include energy market reform, mandatory renewable energy targets, updating electric generation facilities, greenhouse gas abatement programs and reduction of black coal. Growth in aggregate emissions is forecast to be less than GDP growth as a result of slow growth of agriculture, a shift towards natural gas and away from coal for electric power generation, improvements in electricity-supply efficiency, and faster-than-average growth of the service sectors, which do not emit much.

Barry Naughten, ABARE
The Australian MARKAL model has a regional structure with trade in natural gas and electricity among the six states. The focus is to use the model as a policy instrument. They address price-inelasticity of energy services, relatively imminent and stringent targets for abating emissions, and

Table 1. Analysis of "non-optimal" and "no regrets" abatement policies.

Examples of policies and policy settings	'non-optimal' policies	Claimed 'no regrets reduction of greenhouse gases
Mandated renewable electricity target	Portfolio approach unduly favors high cost renewables	Improving international competitiveness of renewables
Energy efficiency programs	Premature scraping of less energy efficient technologies	Correcting imperfect information, principal-agent conflicts, higher hurdle rates
Energy taxes and subsidies	"Distorting' taxes and subsidies	Remover of 'market distorting' taxes and subsidies.
Liberalizing energy markets.	Prolonging lifetimes of existing carbon-intensive assets.	Modular, short lead-time decentralized technologies (with lower hurdle rates) are also less greenhouse gas intensive.

Using MARKAL-MACRO to analyze an R&D portfolio - continued -

Prospective evaluation of the benefits of R&D is challenging for several reasons. Future market and policy conditions that are inherently uncertain play a large role in determining the future economic, environmental and security value of technologies in the R&D portfolio. This study focused on the value of R&D in Energy Efficiency and Renewables, but future advances in conventional energy technologies can affect the value of efficiency and renewable technologies. The approach taken was to estimate prospective benefits of R&D by comparing energy, environmental and economic outcomes under a reference scenario of future market, technology, and policy conditions to alternative scenarios developed through R&D and to compare the reference case with alternative scenarios. The analysis used the U.S. MARKAL and MARKAL-MACRO models. All R&D efforts were assumed to be successful.

Firms generally benefit from increasing R&D to the point where their expected return from an incremental investment equals its cost. Similarly, for society as a whole, R&D expenditures are optimized when marginal costs and benefits are equalized. If firms bear all the costs of their R&D projects and capture all the benefits they provide, private and social incentives will be aligned, and private decisions can be expected to produce an efficient level of R&D.

R&D produces new knowledge about how to do and make things. Both econometric analyses and case

Using MARKAL-MACRO to analyze an R&D portfolio - continued -

studies have repeatedly found that the overall economic return to R&D investments is two to three times as high as the typical rate of return to private investors. Because it is difficult to prevent others from using such knowledge once it exists, R&D performers are generally unable to capture all the benefits from their projects. Since private R&D performers will not take account of benefits captured by others, private markets will systematically invest too little in R&D.

Energy technology R&D has an unusually large potential to provide important social benefits that cannot be captured by anyone in the private sector. These benefits increase the size of the gap between the privately appropriable returns and total social returns, providing additional reasons for public investment in R&D.

A National Research Council committee (2001) used a matrix approach to represent the benefits framework it developed for a retrospective analysis. While recognizing that the challenges of retrospective and prospective assessments differ, this report uses energy-economic modeling to estimate a prospective version of the NRC matrix for the R&D portfolio (Table 1).

The state of the future projected in the reference case is considered the most likely, but certainly not the only possible future. The vertical striped box in Table 1 reflects alternative futures. In a perspective sense, there could be large price-induced shocks depressing energy services levels. Stringent targets, however, that were analyzed in the early 1990s, are not now on the policy agenda over medium-term forecasts. Hence, after initial 'elastic MARKAL' studies in 1995, the inelasticity feature of standard MARKAL (with respect to energy services) has largely been judged an acceptable approximation in most policy analyses. Higher 'hurdle rates' of return on investment are included in certain energy technologies.

Liberalization of electricity markets results in new electricity capacity resulting in greater investment risk, which is now borne by owners and investors rather than consumers/tax-payers. This is reflected in imposed higher technology-specific hurdle rates associated with new investment in technologies characterized by longer construction lead-times; less 'modularity'; and investment in end-use energy conservation. High required rates of return have been reported in numerous empirical studies.

Policy issues include taxes and subsidies on energy flows, mandated renewable electricity targets, requirements that 'electricity retailers and other large electricity buyers will be legally required to source an additional 2 per cent of their electricity from renewable or specified waste-product energy sources by 2010. A key finding of an effect of the mandated target was to bring forward the adoption time of new and renewable technologies.

Table 1 shows examples of policies other than direct penalties on greenhouse gas emissions.

Actual or proposed policies and practices influencing greenhouse gas emissions often differ from the 'theoretically preferred' carbon penalties. Analysis of these issues requires detailed and reliable specification of technologies in a sufficiently broad 'efficient markets' context as well as modelling effects of the theoretically preferred carbon penalties—which remain the 'economic efficiency bench-mark' MARKAL is also well-suited to critical analysis of 'non-optimal' and/or claimed 'no regrets' cases.

Olivier Bahn, Paul Scherrer Institute

MERGE-ETL is a top-down and bottom-up model derived from the nine regions ETA-MACRO model from MERGE 3 (Manne & Richels, 1997) with trading of oil, gas, synthetic fuels, CO_2 permits, and numéraire. The MERGE: optimisation equilibrium model combines 'bottom-up' and 'top-down' approaches. MERGE has been modified to introduce Endogenous Technology Learning (learning-by-doing and learning-by-searching) for selected electric and non-electric energy technologies. A two-factor learning curve was developed. Specific cost is a function of cumulative capacity and cumulative R&D expenditures. It is solved by a heuristic, iterative approach. MERGE is Pre-solved to define equilibrium demands for electric and non-electric energy. Then, ETA-MIP optimises regional energy sectors, and defines cumulative installations and cost dynamics of ETL technologies.

Gary Goldstein

SAGE is the System for Analysis of Global Energy Markets. It is sponsored by the U.S. Energy Information

Administration (EIA) and will be the basis of EIA's new International Energy Outlook. It is a 15-region model with a time frame of 2000 to 2050. It is designed for forecasting and policy assessment. Market share is by groups of technologies. SAGE uses reduced costs to recalculate the market share. The closer a technology is to being competitive, the larger its market share (but share cannot be higher than the winning technologies.) The analyst is forced to consider the marginals. Rigorous documentation will be provided.

Peter Brain, National Institute of Economic and Industrial Research (NIEIR), Melbourne

The top-down approach includes national, state, and regional models. The bottoms-up approach starts with over 200 fully specified individual regional models with input-output relationships and household behavior. The model includes inter-regional trade flows by industry, inter-regional income flows by income type, and explicit linkages to rest of the world.

Denise Van Regemorter, Katholieke Universiteit, Leuven

The distincition between 'top-down' and 'bottom up' is now more a distinction between partial equilibrium and general equilibrium. Different approaches can be found in both modeling strategies for the solution algorithm, temporal horizon, definition of parameters, and objective. The two approaches are complementary. Partial equilibrium focuses on technological content, sectoral allocation, abatement possibilities, and their cost. These are valuable inputs for general equilibrium. General equilibrium addresses welfare cost, choice of policy instruments, and provides a consistent growth assumption for partial equilibrium.

The GEM-E3 Europe model includes 14 EU countries, extension towrds Eastern Europe and Switzerland. There is one model for each country, all linked through trade flows and environmental flows. Environmental issues addressed are global warming, deposition of acidifying emissions, and ambient air quality linked to acidifying emissions and ozone. Energy related emissions include CO_2, NOx, SO_2, VOC, and particulates. Damage computation is made for each country from emissions. Model results suggest a coordinated policy at the EU level with an EU-wide permit system is the least negative approach. At the domestic level, a grandfathered permit system is less negative. General equilibrium effects are important for capturing the complexity of the existing tax and transfers while the partial equilibrium models are important for estimating abatement cost by sector and the specific technologies for reducing emissions.

Using MARKAL-MACRO to analyze an R&D portfolio - continued -

option value to R&D technologies that would provide economically viable solutions under alternative conditions. Models can capture situations where knowledge and technology development in one area affects the way in which other energy technologies are used. For example, technologies that improve in the efficiency of building insulation practices or reduce the generation of waste heat by lighting technologies will lead to changes in the size of heating and cooling equipment used in buildings. Adjustments resulting from these technology interactions can change the economic, environmental, and energy security impacts from those that might be calculated if technologies were evaluated separately, without regard to system interactions.

The reference case projection used to evaluate the impact of the R&D portfolio was benchmarked to the U.S. Energy Information Administration Annual Energy Outlook. There are several important trends in the reference case technology assumptions. Although most technologies' capital costs remain constant at their current level, the cost of a few key technologies are projected to decline over time. These include gas-combined cycle, integrated coal gasification, and renewable technologies. Most of these technologies also see improvements in their heat rates or performances (e.g., capacity factor) between 2000 and 2030.

The R&D portfolio is projected to

Using MARKAL-MACRO to analyze an R&D portfolio - continued -

Table 1. Prospective Benefits Matrix

	Expected	Options	Knowledge
Economic Benefits			
Environmental Benefits			
Energy Security Benefits			

reduce energy expenditures as a result of improved efficiency and lower capital costs.. This does not include welfare gains from the lower cost of energy. The energy intensity of each of the end-use sectors is also projected to decline.

Environmental benefits are primarily reductions in NO_x and CO_2. Security benefits are enhanced by reducing oil intensity, improving vehicle fuel efficiency and creating fuel technology that could reduce and eventually replace imported oil. In electricity generation, technologies will be less concentrated and thus less susceptible to sabotage. Options benefits include value to R&D on technologies that are not being developed primarily to enter the market under the most likely conditions, but would provide viable solutions under alternative plausible conditions.

Often, a research line is pursued because it has limited, but important, expected benefits through niche market applications, but would be expected to have much wider market applications under some alternative futures, e.g., an

Assessment of solar photovoltaic energy systems in Japan

Photovoltaic energy systems have found many niche markets in the developed countries and have brought electricity to remote places in the world. PV may be entering a period of more general applications. High electric prices in California have spawned housing developments with grid-connected PV. Nowhere is PV more utilized than in Japan. Osamu Sato and Masanori Yamaguchi present the current PV situation in Japan.

The growth of residential Photovoltaic systems in Japan has been a key driver for global PV market growth, accounting for about 20% of worldwide generation. The initial success was due largely to a 50% capital subsidy to the end user. The subsidy has dropped to 15-20%, but the demand among environmentally and technologically aware Japanese homeowners is unabated. The subsidy is scheduled to end with the 2002 fiscal year, but the industry appears confident that demand for PV will continue to accelerate (PV Power, issue 16, June 2002.

With increases of consumption in residential and commercial sectors, electricity is becoming more important in Japan's energy system. The best mix of power generation technologies includes small-scale renewable energy technologies, but their current high costs require public support to penetrate the market. MARKAL model studies suggest that the long-term benefit of supporting their market penetration justifies the cost.

Prices of components of PV systems have seen substantial reductions (Figure 1). The short-term progress ratio (PR) of residential PV was 0.88, while the public facility field test (10kW systems) had a much lower PR of 0.68 because of substantial reduction in construction costs (Figure 2). Long term data on the historical prices of the PV module showed a PR of 0.82, consistent with U.S. data. Further reductions in cost will rely on reduction in cost of the PV module. This will require continued research to increase module efficiency and learning in the manufacturing process.

Figure 1. Residential PV prices in Japan

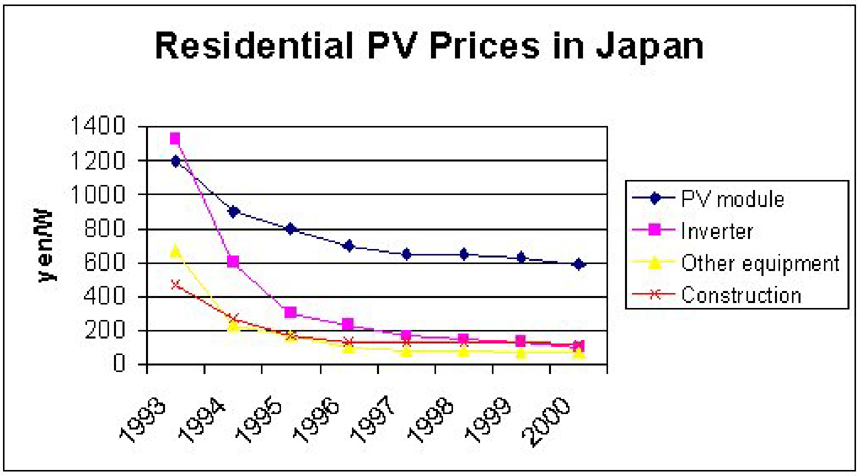
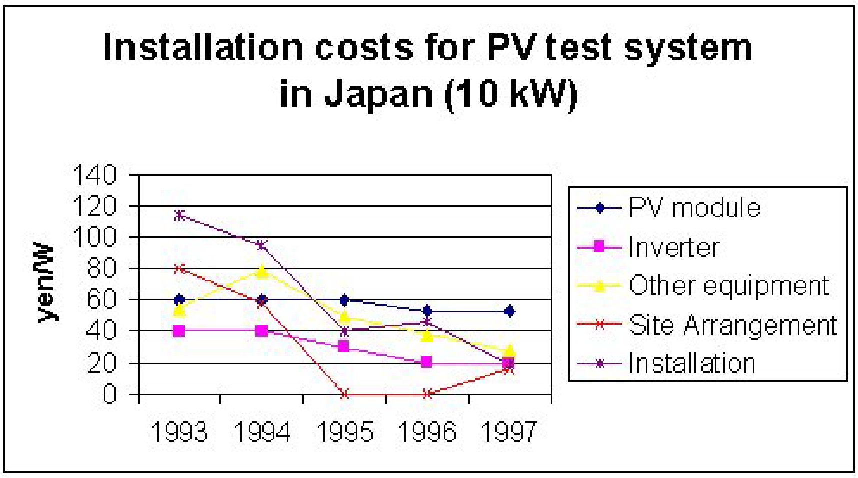


Figure 2. Installation costs for PV test system in Japan (10 kW)



oil disruption. While option values can persist after the research is completed (often referred to as backstop or shelf technologies), the value of the option will change as we move further into the future and are more certain about whether the technology application is economically viable.

R&D can be considered as investments in options that provide opportunities to realize benefits, in the event of alternative future events. In addition to the option of commercialization, R&D investments contain a host of other investment timing options. At each stage, as new information becomes available about the probabilities of different outcomes, choices can be made regarding continuing the research, abandoning the research, mothballing the research, etc. Additional scenarios explored included a high oil price case and a carbon emissions reduction case.

Reference

Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, 2001. *Energy Research at DOE, Was it Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*. Washington, D.C., National Academy Press.

Contact: John Lee

Update on the Energy Technology Perspective Project

ETSAP is supporting the International Energy Agency (IEA) in the Energy Technology Perspective (ETP) project. This is the first time ETSAP has provided direct inputs to EIA. There are four objectives of the program: (1) to develop a global energy technology model to assess technology impact on fuel markets, carbon emissions, and energy security; (2) to identify technology options that can be the most cost-effective in achieving energy policy goals; (3) to provide a basis for designing policies to further development and deploy promising technologies; and (4) to provide a greater technology richness to the World Energy Outlook 2002 and 2004. The global model is based on MARKAL and developed by ETSAP modelers. It provides a time horizon through 2050, covers the whole energy system from fuel extraction to end-use, and covers 15 world regions. There are six IEA regions: US, Canada, Japan, Australia andNew Zealand, IEA-Europe, and South Korea, and nine other regions: Eastern Europe, FSU, China, India, rest of Asia, Latin America, Mexico, Africa, and the Middle East.

ETSAP's role includes testing and final development of TIMES and the VEDA interface: review of the 15 regional models in TIMES; and subjecting regional data and model structure to detailed review. Technology learning effects will be included for key technologies. Additional MARKAL models will be used to study policies at country or regional levels, e.g., the Nordic MARKAL and Australian models.

Priority issues include zero emission technologies (ZET) for fossil fueled plants, e.g., combining fossil facilities with emission capture and sequestration, the impact of oil and gas exploration, and related future technologies. The effort aims to address policies to help in transfer of technology to developing countries, especially India and China. Deployment strategies for industrial technologies and strategies to meet global transport needs with minimal environmental impact are also considered. A final aim is to build a roadmap to a hydrogen economy. The U.S. Energy Information Administration will be documenting about 90% of the model since their version of the model is much the same.

Operating Agent

The IEA/ETSAP Newsletter is published under Annex VIII "Exploring Energy Technology Perspectives" of the Implementing Agreement for a Programme of Energy Technology Systems Analysis". Operating Agent for ETSAP/Annex VIII is the Energy Department of the Politecnico of Torino (http://www.polito.it/ricerca/dipartimenti/dener).

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ISSN 13823264