

International Energy Agency
Programme of Energy Technology Systems Analysis
Annex VIII/IX
*Exploring Energy Technology Perspectives/
Energy Models Users' Group*

Final Report

HIGHLIGHTS

- ❖ Advances were made in the ability to analyze global issues using the ETSAP Tools. ETSAP partners play a key role in all of these, most notable among them:
 - International Energy Agency's development of the *Energy Technology Perspectives* global model to examine the role of advanced technologies in meeting multi-lateral energy, environmental and security goals;
 - U.S. Energy Information Administration adopted and adapted the ETSAP models and methodology to be the foundation for the preparation of its annual *International Energy Outlook*;
 - The European Fusion Development Agreement (EFDA) consortium looking to examine the long-term global potential for nuclear fusion, and
 - ETSAP EMF-22 Integrated Assessment Model (IAM) using TIMES.
- ❖ Several major multi-country/state undertakings employing the ETSAP tools were begun, including:
 - Australia's Agency for International Development sponsored Energy Planning and Systems Analysis Project (EPSAP) involving 8-ASEAN countries and the Asian Center for Energy (ACE) in a coordinated capability building and planning undertaking;
 - European Union NEEDS (New Energy Externalities Development for Sustainability) project developing a 25-member states pan-European energy model using TIMES, which merges energy bottom-up modeling with externalities and life cycle assessment technique;
 - The Northeast States for Coordinated Air Use Management (NESCAUM) is building a 6-state New England-MARKAL model to assess Clean Air Act goals and to support the New England Governors/Eastern Canadian Premiers climate change commitment, and
 - US Agency for International Development is sponsoring an 8-country Southeast Europe Regional Energy Demand Planning initiative to provide a consistent framework for energy planning in the region.
- ❖ A concerted multi-national effort has made the TIMES, an advanced modeling framework poised to be the successor to MARKAL, together with a new user-interface VEDA, ready for mainstream use.
- ❖ MARKAL continued to be used by member countries to evaluate national and local policies for energy, pollution control and emissions trading.
- ❖ The MARKAL/TIMES community has grown to over 50 countries with some 120 government, research and university institutions actively employing the methodology.
- ❖ Continual improvement has been made on the ETSAP website.

Summary of Annex Activities

Summary

In Annex VIII, the Energy Technology Systems Analysis Programme (ETSAP) continued to advance the state-of-the-art of models and methods for analyzing energy systems. ETSAP's more than 20 years of dedication to this commitment is bearing fruit for the ETSAP partners as well as an ever growing number of transition and developing countries. The increasingly widespread adoption of the ETSAP Tools (MARKAL and TIMES and their associated data handling and analysis systems) by governmental and planning institutions across the globe is establishing the methodology as the framework of choice in its field. With countries around the world increasingly concerned about energy security and beginning to think about a post-Kyoto regime, and what this may entail with respect to evolution of their energy systems in what is sure to be a changing world, the ETSAP Tools are poised to make a major contribution to the on-going international cooperation aimed at improving national energy security, reducing greenhouse gas emissions and fostering sustained environmental responsible economic growth.

The overall goal of the Annex was to serve national governments and work in international forums by fostering the development of constructive policy options to reduce emissions of greenhouse gases and to promote the development and use of improved energy technologies. In particular, the aims of the Annex were to encourage:

- ❖ the widespread use of the ETSAP tools, methodologies, data services and knowledge by the governments of the ETSAP contracting parties;
- ❖ the constructive use of ETSAP tools by other countries as well as international organizations in multilateral collaboration, discussions and negotiations;
- ❖ the establishment of linkages with economic and environmental models and approaches that complement the work of ETSAP;
- ❖ the maintenance and ongoing use of the ETSAP worldwide network of systems analysts, and
- ❖ the demonstration and deployment of new methods, with increased flexibility to depict complex energy systems.

There were three principal programs of work in Annex VIII:

- ❖ *International studies and collaborations*, to examine the benefits of international cooperation and trade to meet future requirements to enhance energy security, promote new technologies and reduce greenhouse gas emissions;
- ❖ *National activities and studies*, appropriate to and funded by the individual Participants, aimed at supporting the objectives of this annex, and
- ❖ Ongoing *research and development activities*, primarily to further the development of the TIMES model and its supporting software, the next generation of the MARKAL family of models.

On bilateral and multilateral bases, individual ETSAP participants continued their collaborations, networking, and programs of outreach.

ETSAP Annex IX was also established to foster Outreach to the world-wide community of experts employing the ETSAP Tools (see text of the Annex in Appendix C). The main activity in this regard was an international workshop held in Taipei, Taiwan in April of 2005 (as reported in Appendix I).

More than 50 countries have now been exposed to the ETSAP Tools, with more than 120 institutions currently using the framework world-wide (see Appendix H for a complete list of these countries and institutions). The major activities conducted during Annex VIII are each summarized below.

International Studies, Collaborations, and Contributions

International Energy Agency's Energy Technology Perspective Project: Description of the Model and Its Applications

[Energy Technology Office, IEA Secretariat]

The Energy Technology Policy Division (ETPD) of the Energy Technology Office of the IEA Secretariat has developed a detailed global MARKAL model. This model is now extensively being used by ETPD for energy technology assessments.

System for the Analysis of Global Energy markets (SAGE)

[United States Department of Energy, Energy Information Administration]

ETSAP experts are cooperating with the U.S. Department of Energy's Energy Information Administration to develop the System for Analysis of Global Energy markets (SAGE). The primary purpose of the new modeling framework is to produce annually the "International Energy Outlook" forecasts.

Global Multi-Regional MARKAL Model (GMM)

[Energy Economics Group (EEG) at the Paul Scherrer Institute (PSI), Switzerland]

The primary focus of this work was the development and application of the Global Multi-Regional MARKAL Model (GMM) for the examination of alternative energy development paths and the evaluation of flexible climate policy instruments.

Marginal Abatement Curves in the Energy-System GMM Model

[Energy Economics Group (EEG) at the Paul Scherrer Institute (PSI), Switzerland]

There are several possibilities for considering the effects of non-CO₂ GHG abatement in a "bottom-up" modeling framework. One of them is the explicit inclusion of abatement technologies. The second approach is the use of aggregate marginal abatement curves (MACs), built on the basis of assessment of abatement technologies. This work incorporates marginal abatement curves for two main non-CO₂ greenhouse gases, namely methane (CH₄) and nitrous oxide (N₂O), considering both energy-related and non-energy-related sources, into the Global, Multi-regional MARKAL model (GMM).

Impacts of RD&D on Carbon Mitigation Costs

[Energy Economics Group (EEG) at the Paul Scherrer Institute (PSI), Switzerland]

The MERGE model was used as part of the Swiss NCCR-Climate Program on "Climate Variability and Risk." This effort evaluates the economic advantages of endogenous and induced learning via public and private RD&D spending in support of carbon-free generation technology.

Toward a Nash Equilibrium MARKAL?

[Loulou, Kanudia and Labriet]

A new approach to using employing game-theory to a regionalized global bottom-up model (MARKAL) was developed and applied.

Assessment of abatement costs and permits allocations using World-MARKAL
[Loulou, Kanudia and Vaillancourt]

This effort examined the equitable and realistic allocation of initial emission permits to all countries in the context of a world cooperative climate stabilization strategy. The methodology uses multi-criteria decision analysis (MCDA) to take into account several equity criteria, operationalize and quantify them, and construct a general approach to organize negotiations of permit allowances.

ACROPOLIS - Assessing Climate Response Options: POLIcy Simulations – Insights from using national and international models
[Several ETSAP institutions, and others]

The ACROPOLIS European research project is an attempt to overcome the difficulties linked to the harmonisation of the results from different energy models¹. ACROPOLIS is aimed at applying and comparing several existing energy models to address the potential impact of a number of policy options to reduce greenhouse gas (GHG) emissions.

The European Fusion Development Agreement (EFDA) Consortium to Examine the Long-term Global Potential for Nuclear Fusion: The World TIMES Project
[European Fusion Development Agreement]

The main objectives of the EFDA World TIMES project are:

- ❖ *the construction of a Regionalized World energy/emission model based on the TIMES framework;*
- ❖ *the adaptation of the VEDA interface needed to manage the large databases and to operate the mode;*
- ❖ *the testing of the model on some demonstration scenarios, and*
- ❖ *the delivery of the model and the transfer of the required know-how to EFDA.*

“Climate Policy Scenarios for Stabilization and in Transition“
[ETSAP Participation in EMF-22]

The EMF-22 corresponds very tightly to the objectives of the current and next ETSAP annexes, and constitutes an ideal context for the active development and application of the World TIMES model. ETSAP will actively participate in EMF-22 using a World TIMES model underdevelopment, which includes a new Climate Module.

Asia-Pacific Economic Cooperation (APEC)
[ETSAP Partners from Australia, Japan and the US, plus China]

Among the various models available to the Asia-Pacific Economic Cooperation (APEC) economies, the MARKAL model is used or is under development in no less than 15 of the 21 member economies. This puts MARKAL in a unique position of being able to serve as a common analytic platform for examining issues of interest to the APEC Economies. An assessment was done to examine the maximum potential for renewables in four of these countries (Australia, China, Japan and the US).

European Union NEEDS (New Energy Externalities Development for Sustainability)
[Various EU ETSAP Partners and other EU institutions]

¹ <http://www.ier.uni-stuttgart.de/acropolis>

This project involves the use of energy systems modeling (including scenario building) and the creation of internalization strategies for the 25 member pan-European Community. This research aims at generating partial equilibrium technology rich economic models of each MS/NAC and of the EU as a whole using TIMES. The work will identify, discuss and analyze the terms and conditions (including barriers and enablers) for an effective formulation and implementation of long term strategies based on the internalization of external costs, as well as broadening of the basis for decision support beyond the assessment of external costs by examining the robustness of results under various stakeholder perspectives.

ETSAP Partner Activities

Belgium

Impact of opening the Belgian electricity market: an analysis with MARKAL
[CES KULeuven]

An assessment using the Belgian MARKAL model extended with three neighboring countries (France, Germany and The Netherlands) to permit trade in electricity showed that liberalization of the electricity market can result in improvements of environmental conditions and thus reduce the cost of climate policy in Belgium.

Canada

*Various activities conducted by the Canadian MARKAL/TIMES model team are mentioned in the **International Studies, Collaborations, and Contributions** section of this report.*

Finland

Development of the Finnish National TIMES Model and Case Studies Utilizing the Model
[Technical Research Center of Finland (VTT)]

After the adoption of the Kyoto Protocol in 1997 there was a large demand for a technology program, which could help Finnish companies in the forthcoming strategic decisions in changing operational environment. Therefore, a national technology program, "Technology and Climate Change (CLIMTECH)," was established in Finland. To assess the opportunities and implications of Greenhouse Gas reduction policies a TIMES model for Finland was developed and used.

Ongoing development of TIMES.

Germany

Research using TIMES [Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart]

- ❖ *The assessment of existing and new technologies in the power supply sector.*
- ❖ *The development of methods and tools to study complex systems on different levels of detail with respect to time and geographical resolution.*
- ❖ *Technological and macroeconomic analysis of energy systems to examine climate change protection strategies and the consequences of liberalization of energy markets.*
- ❖ *Ongoing development of TIMES.*

Greece

An Analysis of the Greek Energy System in View of the Kyoto Commitments [Centre for Renewable Energy Sources]

The current Greek Energy System was analyzed to evaluate alternative policies and determine additional measures required in order to achieve the Kyoto targets. Four scenarios were developed, depicting the evolution of the Greek Energy System under alternative policies, taking into consideration medium and high oil prices. Incremental investments and differential costs are then calculated between non-Kyoto and Kyoto scenarios and they are compared to permits costs.

Italy

Evaluation of Green Certificates Policies using the MARKAL-Macro-Italy model

After the ratification of acid deposition and greenhouse gas conventions of Geneva and Rio, domestic energy policies have added the aim of protecting the environment and mitigating climate changes, in line with several European directives. The development of renewable energy sources (RES) is a key strategic measure. The overall impact of the present Italian RES-E obligation were evaluated by means of a model of the Italian energy–environment system built with the MARKAL/TIMES methodology. The contribution of each RES-E presently expected from policy makers to the economic equilibrium mix resulting from computable economic equilibrium scenarios.

TIMES Regional Energy Systems Model for the Piemonte Region [Politecnico di Torino]

This project focused on the modelling of the Piemonte Region using TIMES. The project working steps and current status of our work are presented through the following table where are indicated steps completed by now, steps working progress and future steps. As project results are not yet determined they will be provided as developed.

Debugging a National and Regional Electrical System Model and Implementing the Model in TIMES for Italian Electrical System Research (CESI) [Politecnico di **Torino**]

Activity for CESI deals with development of a national and regional electrical system model and its implementing in TIMES. The structure is based on 20 regions with electrical trade between the neighbors. The project is cooperation among Politecnico of Turin, AIEE (Italian Association Energy Economists) and CESI (Italian Electrical System Research). The activities and status of the project are noted in the table below. As results are not yet available they will be provided at a later time.

Japan

At the Japan Atomic Energy Research Institute (JAERI), the Research Group for Energy System Analysis headed by Mr. Sato made a study on Japan's long-term energy demand and supply toward the year 2050 by applying the Japanese MARKAL model. This study was promoted under the Committee of Nuclear Reactor Development and Utilization of the Japan Atomic Industry Forum, and particular attention was paid on the potential role of nuclear energy in the context of depletion of fossil energy resources and climate change problem. The Research Group made in addition a study on long-term scenarios of developing advanced nuclear power reactors and fuel cycle systems in Japan.

The Netherlands

ECN Policy Studies performed a wide range of activities related to the use of or the further dissemination of the ETSAP tools (the MARKAL model and methodology). These activities covered (model) methodology enhancement (the SAPIENT project), scenario analysis (the ACROPOLIS project), direct policy relevant analysis (the CO₂ QUOTA project) as well as the opportunity to provide training sessions for new users and the given presentations at international fora and workshops (EMF-IEW).

South Korea

An analysis of greenhouse gas reduction potential in power generation, paper industry and household sector was conducted. The purpose of the project is to assess technological reduction potential in these sectors. In addition to this main activity, the training of modelers and outreach initiatives using ETSAP Tools were also undertaken.

Sweden

MARKAL activities at the Department of Energy Technology [Chalmers University of Technology]

Activities at the Department of Energy Technology focussed mainly in two areas:

- ❖ *a continuation of a study on the value of extended transmission capacities between the Nordic countries and northern Continental Europe, and*
- ❖ *work on a better representation of the transport sector in the MARKAL_Nordic model.*

Activities at Profu related to the use of the MARKAL model

All activities during 2004 have been associated to the use of the MARKAL-NORDIC model, which describes the stationary energy system of the four Nordic countries Sweden, Norway, Denmark and Finland. Activities carried out during 2004 may be summarized into:

- ❖ *Analysis of the effectiveness of Swedish climate policy,*
- ❖ *Analysis of a common Swedish-Norwegian market for tradable green certificates (so-called electricity certificates),*
- ❖ *Analysis of a new set of energy and carbon-dioxide taxes, and*
- ❖ *“Linking” the regional MARKAL-NORDIC model to the global IEA-ETP MARKAL model.*

Switzerland

*Various activities of the Energy Economics Group (EEG) at Paul Scherrer Institute (PSI) are mentioned in the **International Studies, Collaborations, and Contributions** section of this report.*

In addition, in collaboration with the University of Geneva, PSI-EGG has undertaken the development of a “bottom-up” energy-systems MARKAL model for Switzerland. The Swiss MARKAL model allows a detailed representation of energy technologies and the assessment of the impact of policy measures on the long-term trajectory of the Swiss energy system (Schulz et al., 2004) and is being used in evaluating long-term sustainability strategies in Switzerland, such as the concept of the 2-kW/capita society.

Turkey

MARKAL was used to analyze different strategies for mitigation of greenhouse gas emissions of the energy sector in Turkey. The methodology has been explained and a reference scenario and three alternative scenarios have been compared in the eventual sections.

United Kingdom

Options for a Low Carbon Future: Review of Modeling Activities and an Update

The background analysis for the 2003 UK Energy White Paper (DTI, 2003a) produced a large number of studies of the technological options for and costs of reducing UK CO₂ emissions by 60% by 2050. More than 70 sets of scenarios and technology assumptions were explored based on the following low carbon technologies and practices.

United States

A Portfolio Approach in Local Energy Planning and Building Upgrades: Case of New York City

The adverse economic impacts of the Great Blackout in America's Northeast in the summer of 2003, coupled with the increasing demand for electric power due to the urban heat island (UHI) effect demonstrates the need for better energy planning and mitigation strategies in major metropolitan areas such as New York City. This study proposes to use a portfolio of models interactively to evaluate mitigation strategies covering demand side management, upgrades in buildings (e.g. green roofs), and distributed electricity generation (building combined heat and power). A detailed New York City MARKAL model will be developed to simulate current and projected energy and electricity demands, electricity transmission and distribution requirements and peak load patterns.

Hydrogen Economy: Opportunities and Challenges

This study examined the transition from a petroleum-based energy system to a hydrogen economy. A hydrogen economy is the long-term goal of many nations because it provides security, environmental, and economic benefits. The transition involves many uncertainties. They include development of fuel cell technologies, hydrogen production and distribution infrastructure, and the response of petroleum markets. This study used the U.S. MARKAL model to simulate the impacts of hydrogen technologies on the U.S. energy system and identify potential impediments to a successful transition to a hydrogen economy.

Evaluating the Pollutant Emissions and Air Quality Implications of Future Technology Scenarios

The U.S. Environmental Protection Agency's Office of Research and Development (ORD) is carrying out several activities involving the use of the MARKAL model to evaluate future technology scenarios. One such activity is the development of pollutant emissions growth factors for ORD's Global Change Air Quality Assessment. The purpose of the Assessment, which is being carried out under the U.S. Federal government's Climate Change Science Program, is to evaluate the air quality implications associated with global change, considering factors such as economic growth, population growth, climate-induced meteorological change, land use and land cover change, technology change, and government policy. The Assessment is a multi-model exercise, involving the linkage of models to address these factors..

U.S. EPA Coalbed Methane Outreach Program

On behalf of the Environmental Protection Agency's (EPA) Coalbed Methane Outreach Program (CMOP) the EPA US-national MARKAL (EPA-MARKAL) model has been augmented to include the ability to track methane emissions from the energy system, and limited other sources (landfills and manure handling). This Methane sub-model includes a wide range of methane emission sources and handling options that could be introduced to mitigate methane emissions. The approach employed could be introduced to other MARKAL models by experienced modelers.

A New England MARKAL Model

The Northeast States for Coordinated Air Use Management (NESCAUM), with the assistance of the International Resources Group (IRG), has developed a New England-specific version of the MARKAL model based on regional data and in cooperation with energy and air quality divisions of the respective states. This planning tool allows for the analysis of a range of transportation, energy and air quality protection programs with a time horizon of 30 years and a focus on the cost and environmental implications of key program design elements.

Systems Analysis and Modeling Tools Research and Development Program]

ETSAP continued its now 25years of tradition advancing the current state-of-the-art with respect to least-cost energy system modeling through the completion of the initial production version of the TIMES model and numerous enhancements to MARKAL.

At the same time major strides were made with respect to the data handling systems for both TIMES and MARKAL. With respect to TIMES the initial version of the VErsatile Data Analyst (VEDA) has been completed and is in use for several major TIMES (and MARKAL) undertakings. ANSWER, the stalwart data handling system for MARKAL saw major enhancements as it gain powerful facilities with respect to the multi-region capabilities needed for the IEA-ETP model.

TIMES

Documentation

Extensive and comprehensive documentation for TIMES has been assembled and is available for the ETSAP website at www.etsap.org/documentation.

What TIMES Adds

TIMES is the evolutionary successor to MARKAL. The main features that TIMES adds on top of MARKAL include:

- ❖ *Fully flexible time periods/years, variable length and data/model year independence;*
- ❖ *Fully flexible time slices, annual/seasonal/weekly/day-night levels all (but annual) user defined;*
- ❖ *More accurate cost representation, annual with construction and incremental investments;*
- ❖ *All "processes" represented uniformly, plus vintaging and aging;*
- ❖ *Representation of intra-process commodity flows;*
- ❖ *More flexible user constraints;*
- ❖ *Time dependent discount/hurdle rates;*
- ❖ *Flexible units: energy, material, economic values;*

- ❖ *Climate module, and*
- ❖ *GAMS code is simpler to understand, maintain and upgrade.*

It is currently being used to support major undertakings including EFDA and NEEDS.

MARKAL

Documentation

Long overdue, the 1983 Fishbone et al MARKAL Users' Guide, sometimes previously not so affectionately referred to as "the bible," has finally been replaced. The new documentation strives to both provide a substantive background as to the principles embodied by MARKAL, as well as elaborate the full details associated with both the input data, its relationship to the model structure, and the mathematics itself. The complete documentation is available from the ETSAP website at www.etsap.org/documentation.

IEA ETP Enhancements

This modeling activity is built on the MARKAL energy system model developed by the Energy Technology Systems Analysis Programme, a long-standing Implementing Agreement under the auspices of the IEA.

In the course of constructing the International Energy Agency's (IEA) Energy Technology Perspectives (ETP) global model several enhancements were made to MARKAL that will immediately benefit the ETP project, as well as the global community of MARKAL users.

Data Management and Analysis Systems ("Shells")

VEDA

The Versatile Data Analyst (VEDA) supports both MARKAL and TIMES. VEDA consists of two independent but closely related software, VEDA-Front-End (VEDA-FE), which oversees the management of the input data and submitting of model runs, and VEDA-Back-End (VEDA-BE) used to analyze the results of the model runs. VEDA was explicitly developed to support the increased complexity associated with developing and applying large multi-region models.

VEDA is now being used for the major multi-region modeling initiative including the global models of the Energy Information Administration (SAGE), European Union (NEEDS), and European Fusion Development Agreement (EFDA), and the New England MARKAL undertakings.

ANSWER

During Annex VIII, the ANSWER continued to be developed to meet the needs of the expanding MARKAL user community. The single most important development was the creation of a special version of ANSWER tailored to meet the needs of the International Energy Agency's Energy Technology Perspectives (IEA-ETP).

The current ANSWER user base includes about 90 institutions in some 35 countries.

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