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Introduction to ETSAP Tools
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Presentation Outline
- Overview of the ETSAP Tools
- Typical Applications
- Key Users
Overview of ETSAP Tools

ETSAP Tools Overview

- MARKAL and TIMES model generators are developed under the auspices of the International Energy Agency’s Energy Technology Systems Analysis Programme (IEA-ETSAP, www.etsap.org)
- Model generators are written in the General Algebraic Model System (GAMS) and solved with commercial solvers
- “Friendly” user interfaces for managing input data, running model generator, examining results (ANSWER and VEDA)
- In use at some 200 institutions in over 60 countries
- Users have developed, and continue to develop hundreds of models assembling an appropriate database for each model instance
Merits of MARKAL/TIMES

- Widely used, proven and continually evolving model for assessing a wide range of energy and environmental planning and policy issues.
- Flexible, verifiable and adaptable methodology for supporting global, regional, national and local decision-making.
- Encompasses all sectors of the energy (and materials) system to ensure a comprehensive assessment of interdependencies as sectors compete for limited resources (energy and fiscal), as well as the co-benefit arising from policy actions.
- Analytic framework is ideally suited for assessing the role of technology in achieving environmental and policy goals.
Model Characteristics

- Encompasses *entire energy system* from resource extraction through to end-use as represented by a Reference Energy System (RES) network.
- Level of detail is *scalable* from municipality through to entire country, or multi-country to global.
- “Bottom-up” *technology-rich* – essence is technology choice among competing technologies.
- Captures *interaction* between demand and supply side actions.
- Typically run out 20-50 or more *years into future*.
- Identifies most *cost-effective* pattern of resource use and technology deployment over time under varying constraints and alternate futures.

Simplified Reference Energy System

[Diagram showing the simplified reference energy system with resource extraction, refining and conversion, transport, conversion, transmission and distribution, utilizing device, and end use categories. Various resources such as renewables, nuclear, coal, natural gas, and crude oil are shown, along with end uses such as electric, heat, solid, gas, liquid, and specific industries.]
MARKAL Energy Perspective

**Primary Energy Supply**
- Renewables e.g.
  - Biomass
  - Hydro
- Mining e.g.
  - Crude oil
  - Natural gas
  - Coal
- Imports e.g.
  - Crude oil
  - Oil products
- Exports e.g.
  - Oil products
  - Coal
- Stock changes

**Conversion Technologies**
- Fuel processing
  - Plants e.g.
    - Oil refineries
    - Hydrogen prod.
    - Ethanol prod.
- Power plants e.g.
  - Conventional
  - Fossil Fueled
  - Solar
  - Wind
  - Nuclear
  - CCGT
  - Fuel Cells
  - Combined Heat and Power

**End-Use Technologies**
- Industry, e.g.
  - Steam boilers
  - Machinery
- Services, e.g.
  - Air conditioners
  - Light bulbs
- Households, e.g.
  - Space heaters
  - Refrigerators
- Agriculture, e.g.
  - Irrigation pumps
- Transport, e.g.
  - Gasoline Car
  - Fuel Cell Bus

**Demand for Energy Service**
- Industry, e.g.
  - Process steam
  - Motive power
- Services, e.g.
  - Cooling
  - Lighting
- Households, e.g.
  - Space heat
  - Refrigeration
- Agriculture, e.g.
  - Water supply
- Transport, e.g.
  - Person-km

Model Characteristics (Cont.)

- Evaluates all options within context of entire energy / materials system by:
  - balancing all supply/demand requirements
  - ensuring proper process/operation
  - monitoring in detail each process’s capital stock turnover
  - adhering to user defined environmental & policy restrictions.

- Computes an equilibrium on energy markets that takes into account impact of policies on:
  - energy and product prices
  - technological development
  - energy security (trade)
  - attaining environmental goals
  - consumer behavior (e.g., miles driven, warming/cooling homes)
  - industrial output and profitability.
Model Characteristics (Cont.)

- Provides framework for exploring and evaluating alternative futures, and role of various technologies, trade and policy options.
- Able to interact with other models used to assess regional issues, most notably dispersion and environmental impacts models, forestry/agriculture models and more detailed econometric models.
- Employs an open and well understood approach to both data assumptions and modeling technique.
- Facilitates stakeholder buy-in and participation by promoting communication between the various decision-making bodies.

Assessing Energy, Economy, Environment & Trade Interactions
MARKAL/TIMES Shortcomings and Remedies

- Data intensive characterization of technologies and a region’s reference energy system used to be labor intensive. But, new global data bases and automated tools to mine these databases has improved the situation.
- Results sometimes sensitive to small changes in data assumptions. However, stepped supply curves and market share algorithms remedy this.
- Limited ability to model consumer behavior. However, growth constraints, damping costs, “hurdle” rates, and demand elasticities partially remedy this.
- Limited representation of jobs and GDP impacts of energy policy. But “linkage” to economy-wide models being pursued.

MARKAL/TIMES Relative Advantages

- Well understood modeling paradigm, least-cost equilibrium computation (efficient or regulated markets).
- Coherent and transparent framework, where the data assumptions are open and each result may be traced to its technological cause.
- Has a well-developed support network around the world through ETSAP (Energy Technology Systems Analysis Programme of the International Energy Agency).
- Has been in existence and used in a non-research environment since 1980.
- Employs a user-friendly “shell” which oversees all aspects of working with the model and interfaces with MS-Office.
- Quick turnaround time (1-region model in under a minute) with no iteration.
- Open data and model architecture.
MARKAL Data Requirements

- Useful Energy Demands / Energy Services (and Elasticities)
- Detailed Costs
  - Resource, investment, fixed, variable, fuel delivery, hurdle rates
- Technology Characteristics
  - Fuels in/out, efficiency, availability, technical life duration
  - Resource supply steps, cumulative resources limits, installed capacity of technologies, new investment possibilities
- Environmental Impacts
  - Unit emissions per resource, per technology (operation, investment)
- System and other parameters
  - Discount rate, seasonal/day-night fractions, electric reserve margin

Producer/Consumer Equilibrium and Elastic Demands

![Graph showing producer and consumer equilibrium](image_url)

- Price vs. Quantity
- Demand curve (fixed demand)
- Supply curve
- Equilibrium price
- Equilibrium demand

Courtesy IER-Stuttgart
Producer/Consumer Equilibrium for each Commodity w/ Technology Detail

Power plants
ROR = run of the river
HB = hydro basin
PC = pulverized coal
CC = combined cycle
LWR = existing nuclear
GT = gas turbine
SF = steam fossil
others existing
KGE = oil fired GCC
EPR = new nuclear
PC = fuel cells
Wt = wind offshore
BE = biomass steam
GEO = geo hot dry
PV = photovoltaic

Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

ANSWER Overseas Model Use
Network & Comparison of Technology Costs
ANSWER “Smart” Templates

VEDA-FE Handles Model Data
VEDA-BE Handles Results

Primary MARKAL Results

Constant Emission Reduction Indicator (CERI)

Base Case
CDM Case
NG Case
Primary MARKAL Results (Cont.)

Contribution to Carbon Reduction

Year

Thousand Ton CO2

0 5000 10000 15000 20000 25000


Primary MARKAL Results (Cont.)

Electricity Generation (Billion kWh)

2010 2015 2020 2025 2030 2035 2040 2045 2050

ML-NOF ML-OFF PP_REN PP_PSTG PP_OIL PP_NUK PP_HYDRO PP_GASCCS PP_GAS PP_COALCCS PP_COAL
Typical Applications

Typical Applications - Policy

- Mandatory micro-measures in each sector: building code, building retrofit programs, modal-split incentives in freight and passenger transports, energy efficiency programs, etc. vehicle standards
- Energy taxes, investment subsidies (e.g., green and white certificates, clean/efficient technologies)
- Renewable portfolio standards
- Energy security evaluation (oil/gas/nuclear fuel imports energy options evaluation)
- Merits of education, information dissemination
- Impact of social constraints, e.g. nuclear
Typical Applications – Technology Evaluation

- Analysis of competitiveness of technologies or energy chains (gas or district heating grid?) under different economic assumptions and market barrier removal
- Assesses bundles of competing and/or of complementary technologies, rather than stand-alone evaluations
- Life-cycle analysis in a dynamic setting (cradle-to-grave)

Typical Applications - Environmental Issues

- Emission taxes, incentives to non polluters; tax redistribution issues
- Emission Cap-and-trade systems: global or partial coverage, multiple bubbles, etc
- Hybrid system: caps + ceiling on emission price
- Emission intensity standards and regulations
- Effects of internalising environmental externalities
- Alternative allocations of emission rights to regions, sectors. Lumped allocations versus output-based allocations
- Energy intensive materials and urban solid waste management
What MARKAL Does Not Do

- Preparing energy, technology, emissions, economic forecasts (exception: SAGE variant, at US-EIA)
- Representing and studying the behaviour of monopolistic markets
- Evaluating the amount of available fossil or renewable reserves and ultimate resources.
- Analysing the effects of non co-operative games (exception: the Nash equilibrium version at GERAD, Canada)
- Studying the global climate and its effects (exception: the climate equations have been internalised in TIMES)
- Studying the social behaviour towards energy options, in term of consumer preference or acceptability of an option

Major Users / Applications
Major Global MARKAL/TIMES Models

- International Energy Agency (IEA): Energy Technology Perspectives (ETP) project; bring technology detail to *World Energy Outlook* scenarios.
- ETSAP TIMES Integrated Assessment Model (TIAM); EMF-22 development of hedging strategies
- European Fusion Development Agreement (EFDA) consortium; examine long-term global potential for nuclear fusion.

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Major Regional MARKAL/TIMES Models

- Natural Resources Canada: National Climate Change Implementation Process analysis of national GHG policies
- AUSAID/ASEAN: Energy Policy Systems Analysis Project (EPSAP); 8-country + regional center (ACE) capability building and planning initiative
- EC NEEDS (New Energy Externalities Development for Sustainability) project; 28 states pan-European model; examine externalities and life cycle assessment issues (and follow-on projects for renewables (RES2020) and energy security (EACCESS))
- Italian 20-region electricity local planning framework
- USAID Southeast Europe Regional Energy Demand Planning (SEE-REDP) project; establish common framework for assessing demand-side opportunities
- U.S. EPA-ORD US9r modeling: Climate Change Air Quality Assessment (AQA); identification of technology pathways and emission profiles
- Northeast US 12-state model for examining air quality and climate change issues, and cooperation

<p>| ETSAP | ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAMME |</p>
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Selective ETSAP Partner MARKAL/TIMES Activities

- UK Department of Trade and Industry for “Options for a Low Carbon Future – Phase 2+3” analysis
- Second National Communication of Italy for the United Nation Framework Convention on Climate Change.
- US examination of GHG reduction proposals under consideration in the US Congress (for Natural Resources Defense Council)

Other MARKAL/TIMES Undertakings

- Numerous key institutions in China (Energy Research Institute, Tsinghua University, HK-EPD, GETRC, GRIEP, CUMT, SAES) and India (TERI, IIMA) to examine reform and energy sector evolution to meet economic development goals, and to develop multi-region national models.
- The APEC EWG to examine the maximum cost-effective level of renewable electric generation in 4 APEC economies.
- Government and university partners in 3 Central America countries to establish baselines and evaluate opportunities within the realm of Climate Change as part of a USDOE/AID co-sponsored project.
- Bolivia Programa Nacional de Cambios Climaticos; develop GHG reduction strategies, including modeling of forestation as a carbon reduction option.
Other MARKAL/TIMES Undertakings (Cont.)

- University of Cape Town – Energy Research Centre (ERC); SA national energy and environmental planning, regional assessment of energy, rural energy issues, etc.
- Research institutions and universities in 5 European countries participating in the IEA – Annex 33: Advanced Local Energy Planning; to apply MARKAL at the municipal level.
- Numerous universities and regional institutions in support of Advanced Local Energy Planning (ALEP).
- Research institutions and universities in over 60 countries around the world; to look at sustaining economic development in the context of energy/ environmental issues ranging from Climate Change to local air pollution.