D 3.1e : Economic Analysis Report

- Examination of Existing Analysis & Planning Tools -

Component 3
Support to the Ad hoc Group
Economic Analysis

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1 INTRODUCTION

The following report identifies and reviews the Energy Analysis and Planning models used throughout the 12 Mediterranean Partner (MP) countries taking into account the energy characteristics of each country and those of the region.

Energy planning and analysis tools globally have evolved in response to changes in the emphasis of energy policies. Following the oil crises of the 1970's, policy issues related to energy security and the price of fossil fuels. Policy issues are now dominated by market reform, sustainable development and global climate change.

The need to represent the growing process of market liberalisation has motivated modellers to adopt market oriented modelling approaches. Integrated energy system analysis has become more flexible. The focus of developers of large energy system models in recent years is structuring the models in modules. The modular structure allows them to be run either as full integrated models often with links to other large models and data bases or where the modules can be run as stand alone models at the technology, sector, national or regional level.

Currently, most MP countries economic analysis and data availability on their respective energy sectors depend on national guidelines for energy policy and the availability of domestic energy resources. Only some of the MP countries provide information that is harmonised with international guidelines.

In addition to the models used by state authorities in each of the MP countries, with the introduction of market reform, the participation of foreign and local private capital and investment in the region has in some of the MP countries enhanced energy planning and analysis.

The following section, Section 2 Methodology, specifies the approach and the tasks undertaken to identify and review the energy analysis and planning tools used throughout the region. Section 3 provides an overview of energy system analysis. Section 4 summarises the application of the tools in use in the region. Section 5 provides a presentation of the tools in use in the region. Section 6 summarises international standards in energy planning and analysis. Section 7 provides conclusions to the review.

2 METHODOLOGY

The following review of the energy analysis and planning tools used throughout the Mediterranean Region is based on desk research carried out on public domain information sources in preparation for the first ad hoc meeting of the Euro Mediterranean Forum.

The developers of the identified models in use in the region have been contacted to determine where and to whom the models have been provided. Each recipient organisation identified has been contacted to identify to what extent the model is been utilised and for what purpose it is been applied across the region.

A Tool Definition Document (provided separately) has been prepared on each tool currently in use throughout the region. The Tool Definition Document (TDD) provided is designed to capture all the key features of the tools under study. Each examined tool is described in its own TDD in a formal and uniform fashion allowing for comparative analyses and assessments.

A presentation of the models in use in the region has been prepared to supplement the TTD.

A summary of international standards in energy planning and analysis has been prepared as an indication of the development of energy planning in the Mediterranean region compared with the level of planning and analysis that is carried out in the EU and the US.

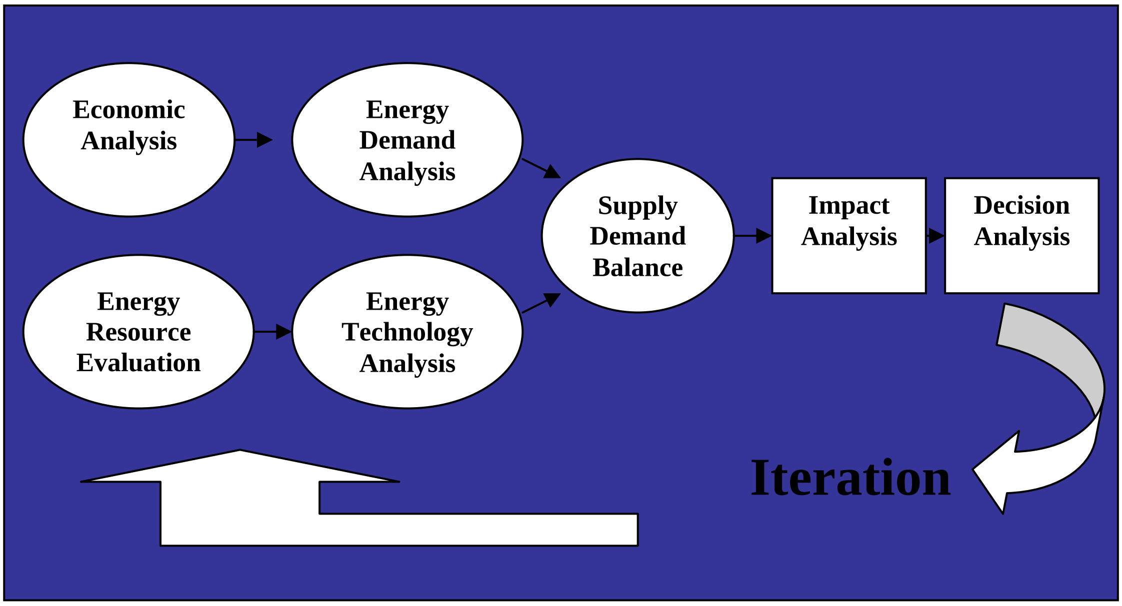
The following sections provide

- Overview of Energy System Analysis
- Identification of Energy Planning Tools in use in each MP country
- Review of the application of the tools in each MP country
- Presentation of the features of each tool used in the MP Countries
- International Standards in Energy Planning and Analysis
- Conclusions

3 OVERVIEW OF ENERGY SYSTEM ANALYSIS AND AVAILABLE TOOLS

There are numerous energy planning models and tools that are in use globally. The following is a general schematic of Energy System analysis. It is a broad characterisation which is useful in grouping the kinds of activities that are involved

Figure 1: Analysis of Energy Systems



Economic Analysis is the evaluation of growth and development in the various sectors of the economy. It considers the historical behaviour of macroeconomic features (gross domestic product, employment, population, etc.) and how they might change in the future.

Energy Demand Analysis considers the activities in individual energy-consuming sectors of the economy (industry, transportation, residential housing, commercial buildings, etc). It relates the macroeconomic developments to the energy that will be required in each sector to support that development. As such, it is a microeconomic view of energy needs.

Resource Analysis considers the energy resources that might be available. Fossil fuels, renewable resources, nuclear materials, and imported energy are evaluated in this part of an analysis.

Technology Characterisation addresses the various energy technologies that might be used to supply the energy needs. Issues of technology performance, life cycle cost, and environmental discharges are considered. The characterisation effort deals with the assembly of information in a consistent and useable form.

Supply/Demand Balance is the process of matching the available energy resources and technologies to meet the demands generated by each sector of the economy. It is an integration of the supply and demand elements of the analysis.

Impact Evaluation addresses the environmental impacts that an energy system configuration will have. It includes consideration of emissions, transport of pollutants, exposure, effects on people as well as ecosystems, and valuation of those effects.

Decision Analysis is the procedure used to assemble the vast amount of information generated by the other parts of the analysis and combine it into a suitable form for decision making.

Energy Analysis and Planning tools have been developed in several different levels of technology complexity and modelling scope. For comparison purposes they can be divided into three models in three categories—

- technology-level,
- sector-level, and
- economy-level energy planning.

These three levels of models have different objectives.

Technology Level Model
The technology-level model is used to select individual components of a single system. The technology-level model is less complex in terms of the number of issues involved than sector-level and economy-level energy models since the model is used to satisfy one single objective an energy system design at a specific site and for a specific application. Unlike the other two models, a compromise does not need to be made among conflicting objectives. The data required to run the model is simply the data at the specific site (for example, resources supply and energy demand at the site where the system will be located) and the specific technology to be used (for example, hybrid system of wind and diesel). The data required can be very detailed and difficult to obtain, for example, hourly wind data for multiple heights and multiple years for a specific site.

Sector Level Model
For energy, the most widely used sector model is an electric utility model. The sector-level model, such as an electric utility model, is adopted to define the least-cost fuel mix for electricity generation to meet an economy's future electricity demand, (for example WASP). A sector model generally examines a single energy sector in detail. To meet this purpose, the information on various electric generating technologies, fuel options, and demand-side options are needed.

Economy Level Model
In comparison, the economy level energy model is utilized to facilitate the decision to provide the economy with energy supplies to satisfy the future energy demand at the least cost by taking into consideration issues such as energy security, energy diversification, new technologies and environmental related problems. (for example ENPEP, LEAP, MARKEL and PRIMES). There is a lack of set rules on what factors or resource attributes are required in an economy-level energy model to make it an ideal model for an economy's energy planning.

Data Requirements
The data required to calibrate the models and factors influencing the decisions in the planning process are different among these three model levels and even between different economy level models. Some of the economy level models or energy system models contain the sector and or the technology level of modelling either within the models as part of a suite of modular packages which can be operated standalone or as part of the system level of modelling.

Table 3 below shows an Indicative list of the Energy Planning and Analysis Tools in use globally.

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(IAEA Models)

ENPEP Energy and Power Evaluation Program
(ENPEP contains a set of analytical tools for use in integrated energy-environmental planning)

MAED
(MAED is used to prepare forecasts of electricity demand that are consistent with a countries' economic and industrial development objectives and possibilities)

WASP (Wien Automatic System Planning Package)
The Wien Automatic System Planning Package is the IAEA's most popular and long lived tool for electricity system planning.

GTMAx (The Generation and Transmission Maximisation Program)
is a premier analysis tool for deregulated electricity markets.

EMCAS (The Electricity Market Complex Adaptive Systems)
is a new agent-based model for long-term simulation of competitive electricity markets.

EIA Models

NEMS The National Energy Modeling System (NEMS) is a general equilibrium model of the interactions between the U.S. energy markets and the economy.

EC Models

PRIMES	(General Equilibrium Model)
POLES	(Prospective outlook on Long term Energy Systems)
(GEM-E3)	(General Equilibrium Model for Energy-Environment-Economy)
HERMES	(Top down Macro energy Model)
QUEST	(Top down Macro Model)
MIDAS	(Energy Demand & Supply Model)
MEDEE	(Energy Demand and Socio Economic)
EFOM	(Linear Programming Model for Optimisation of Supply & Demand)

IEA Models

MARKAL Market Allocation Program (Brookhaven National Laboratory BNL for IEA)

Other Models

LEAP Long-range Energy Alternatives Planning
(Stockholm Environment Institute Boston Center &UNEP)

MARKAL Market Allocation Program (Brookhaven National Laboratory BNL)

MESAP Modular Energy Planing Package University of Stuttgart

4 ANALYSIS AND PLANNING TOOLS USED IN THE MP COUNTRIES

Currently most MPs economic analysis and data availability depends on national guidelines for energy policy and the availability of domestic energy resources. Table 4.1 below shows the existing planning tools identified to date that are in use in the MP countries .

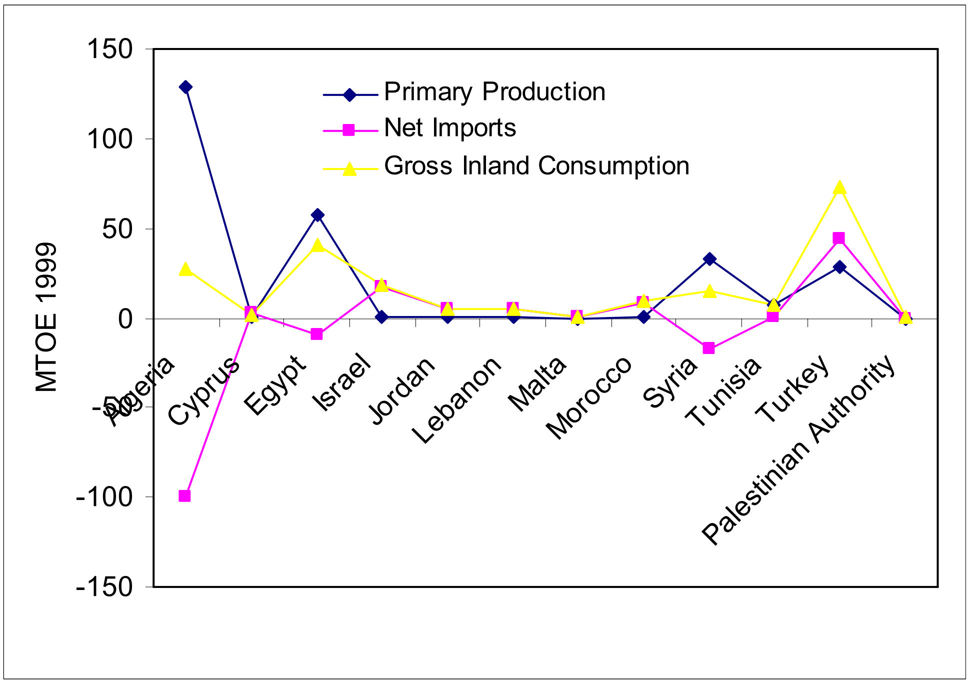
Table 4.1: Energy Analysis and Planning Tools used in the MP Countries

Country	Organisation	Energy Analysis and Planning Tools Used	Application
Algeria	SANELGAZ SONATRACH	ENPEP, MAED-1 & WASP-III (portion of ENPEP) LEAP	Sonatrach has requested training on LEAP
Cyprus	National Technical University of Athens	Primes Ver 2 Model GEM –E3 Model	Alternative Scenarios for the Future Evolution of the Cypriot Energy System
Egypt		ENPEP LEAP	Energy economy model of Egypt Energy Demand simulation Model. Greenhouse gas abatement project.
Israel	Ministry of Energy and Mineral Resources & ICAF	LEAP (Under Consideration)	
Jordan	Ministry for Energy and Mineral Resources	ENPEP LEAP	Energy Demand Forecasting and Electricity Supply Optimisation
Lebanon	No official Authority. Lebanese Association for Energy Savings. (ALAMEE)	LEAP	Energy Demand Forecasting
Malta		LEAP	
Morocco	Consulting Company ADS	LEAP	Climate mitigation analysis for UNFCCC
The Palestinian Authority		LEAP	
Syria (Mashrek)	Ministry of Energy Syrian Atomic Energy Commission	LEAP WASP-6	
Tunisia (Maghreb)	Energy Agency Ministry of Environment	MARKAL LEAP	
Turkey	Electrical Work Studies Directorate (EIEI) & Ministry of Energy and Resources	ENPEP MAED WASP III MARKAL	Energy Demand Forecasting Energy Supply Optimisation.

4.1 Review of the Application of Analysis and Planning Tools in the MP Countries

The application and suitability of the energy planning and analysis models throughout the MP countries is in part influenced by the availability of energy resources in each country. In terms of primary energy resources the region varies significantly from country to country. Algeria's primary energy production in 1999 was 128 Mtoe amounting to 50% of total primary energy production in the region. The remaining 50% of production in 1999 was divided between Egypt, Syria, Tunisia and Turkey. As shown in Figure 4 Cyprus, Jordon, Lebanon, Malta, and the Palestinian Authority have no primary production of energy and Israel and Morocco produced less than 1 MTOE of primary energy in 1999.

Figure 4:
Primary Production, Net Imports and Gross Inland Consumption in the 12 MP Countries (MTOE) 1999.



4.1.1 Algeria

Sonelgaz the State power company has used portion of ENPEP MAED for electricity demand forecasting and WASP for least-cost generating system expansion. According to Sonelgaz the sector requires billions of dollars in investment. Algeria is one of the countries in which The IAEA has a liaison officer for ENPEP. Sonatrach the State oil and Gas company have requested training on LEAP. The energy sector is to be opened up to private (including foreign) investment which can be expected to increase energy planning and analysis tools in use.

4.1.2 Cyprus

The National Technical University of Athens has used the PRIMES model (Version 2) in 1998 to develop three alternative scenarios of the Cypriot Energy System to 2020. The scenarios aim to reliably simulate the most likely evolution paths of the Cyprus Energy System both from the supply and demand point of view. The general macro economic environment remains the same for all three scenarios and is based on the results of the base line macro economic scenarios already run with the use of the GEM-E3 (General Equilibrium Model), adapted and calibrated for the Cyprus economy.

The purpose of the exercise is twofold, to investigate current trends of the Cypriot energy system taking into account existing energy policies and to analyse the implications of alternative energy policy measures. The output of the PRIMES model takes the form of a set of detailed energy balance sheets, power generation balances, refining, gas and new fuel supply balances, investment programs and results about costs and prices of energy.

4.1.3 Egypt

ENPEP has been used in Egypt to construct the energy economy model of the country and forecast energy demand in addition to a greenhouse gas abatement project.

4.1.4 Israel

The Stockholm Environmental Institute were recently in discussions with the University of Haifa about using LEAP for an energy master plan for Israel.

4.1.5 Jordan

The Ministry for Energy and Mineral Resources have used ENPEP for energy demand forecasting (MAED) and least cost generation capacity expansion (WASP III). Jordan has a IAEA Liason Officer for ENPEP.

4.1.6 Lebanon

There is no official authority in Lebanon for energy planning. However the Lebanese Association for Energy Savings. (ALAMEE) has received the LEAP software.

4.1.7 Malta

LEAP has been provided to Malta but it is not known to what extent it is in use.

4.1.8 Morocco

The Stockholm Environmental Institute has provided a small amount of training on LEAP to a consulting company ADS who have been using LEAP to carry out climate mitigation analysis for their report to UNFCCC. The use of LEAP was very limited given the data available. ADS completed an energy demand forecast to 2020, offer/demand balancing and emissions evaluations. ADS were not successful in completing the mitigation scenarios and the resources optimisation. Recommendations were made by ADS to the Ministry of energy on how to improve the use of LEAP for the second Moroccan communication to the UNFCCC.

4.1.9 The Palestinian Authority

The PEA has recently established two new departments, the Energy Department and Nuclear Energy and Radiation Protection Directorate (NERP) The Energy Department is responsible for overall planning, regulation and control. The NERP is responsible for policy making and legislation promotion.

4.1.10 Syria

The Ministry of Energy in Syria is currently using LEAP. WASP-6 is available from the Syrian Atomic Energy Commission and a number of AECS-staff have been trained in Vienna on its use. GEMIS-4.07 & KEA, both developed by Oeko-Institute under contract with WB, GTZ & Dutch Cooperation, to MoEl, AECS and Ministry of Environment. However all of them need basic training in their use.

4.1.11 Tunisia

In the early '90s Tunisia received MARKAL training with support from the Canadian government, but the institutional knowledge is long gone. The Ministry of Environment has requested training on climate mitigation analysis on LEAP from the Stockholm Environment Institute, but no funds have been found so far.

4.1.12 Turkey

Under a World Bank funded project experts from Turkey's Ministry of Energy and Natural Resources (MENR) and the Turkish Electricity Transmission-Generation Company (TEAS) have been trained in the use of various ENPEP modules. Currently ENPEP is being used for the analysis of a variety of GHG mitigation options, including T&D loss reduction, demand-side management (DSM), market based instruments, and increased renewables.

A bottom-up demand analysis model (MAED) is used to develop the energy demand projections. The electricity demand forecast is fed into the power system expansion model (ELECTRIC or WASP). The expansion plan and the demand projections for the other fuels and sectors are transferred into BALANCE. BALANCE uses a non-linear, equilibrium approach to determine the energy supply and demand balance for the entire energy system.

5 PRESENTATION OF ANALYSIS AND PLANNING TOOLS IN USE IN THE MP COUNTRIES

Each of the energy planning and analysis tools identified in Table 3.2 above are reviewed in the following sections. The tool definition document (TDD) provided in Appendix 1 captures all the key features of the models.

5.1 Energy and power evaluation program (ENPEP)

ENPEP was developed by Argonne National Laboratory (ANL), with support from the U.S. Department of Energy, International Atomic Energy Agency (IAEA), the World Bank, and the Hungarian Electric Board. The IAEA has liaison officers for the entire ENPEP package or part of in over 90 countries including 8 of the 12 MP countries.

BALANCE uses a market-based simulation approach to determine the response of various segments of the energy system to changes in energy prices and demand levels. The model relies on a decentralized decision-making process in the energy sector and can be calibrated to the different preferences of energy users and suppliers.

Basic input parameters include information on the energy system structure; base year energy statistics, including production and consumption levels, and prices; projected energy demand growth; and any technical and policy constraints.

Extensive training and experience are definitely required in order to work successfully with the model.

5.1.1 Model Structure

The ENPEP model is composed of 9 sub-modules as shown below:

- *MACRO.* The MACRO module is used to format macroeconomic growth projections for use in developing energy demand projections.

- ***DEMAND.*** The DEMAND module is used to project energy or fuel demand based upon the macroeconomic growth rates generated by the MACRO module, and to generate a set of energy demand growth rates for use by the BALANCE module.

- ***PLANTDATA.*** The PLANTDATA module serves as a library of basic information about thermal and hydroelectric generating facilities for both the ELECTRIC and BALANCE modules. It was created to reduce redundancy and provide a convenient way to enter the required large quantity of data.

- *BALANCE.* The BALANCE module is used to project an energy supply and demand balance for any study period up to 75 years.

- *LDC.* The LDC module is used to transform data and perform calculations necessary to prepare input data on electricity generation requirements for the ELECTRIC module.

- *MAED (Model for the Analysis of Energy Demand).* MAED is a simulation model that can be used for long-term energy and electricity demand forecast.

- *ELECTRIC.* The ELECTRIC Module is a microcomputer version of WASP-III (the Wien Automatic System Planning Package). It calculates an electrical generating system expansion plan that meets demand at the minimum cost, subject to system requirements (for example, reliability).

- *ICARUS (Investigation of Cost and Reliability in Utility Systems).* The ICARUS module is a detailed dispatch model that can be used to assess the reliability and economic performance of alternative expansion patterns of electric utility generating systems.

- *IMPACTS.* The IMPACTS module is used to estimate environmental residuals and esource requirements for the energy supply system (electric and nonelectric) that are determined by the BALANCE and ELECTRIC modules.

The BALANCE module is based on the approach of generalised equilibrium modelling, based on the concept that the energy sector consists of autonomous energy producers and consumers that carry out production and consumption activities, each optimising individual objectives.

The model estimates energy consumption and its associated costs, based on the designed energy network. Various nodes make up the energy network. Each node represents energy activities or processes in an economy from energy production (and/or import, export), conversion, transportation, distribution, to energy consumption by end use sectors. Nodes of the network are linked. The relationship between the nodes and links specifies the transformation of energy quantities and processes through the various stages of energy production, processing, and use within the energy network.

BALANCE uses this description of the energy sector and demand projection to “balance” energy supply and demand based on an equilibrium approach. That is, it finds a set of prices and quantities that satisfy all equations and inequalities.

5.1.2 Data Requirements

BALANCE requires an extensive set of data for the designed energy network. However, the model is flexible in the degree of detail that is built into the energy network. The energy network can be designed to be a simple one to fit the data availability or to be a complex one for more detailed analysis if data is available. The data required to execute BALANCE is a completed set of quantities and prices of the energy system in the base year and the projection data of all the forecast years, which can be listed as follows;

- Base-year quantities of all resources consumed (both domestic and imported
- resources);
- Base-year allocation of each resource to each device;
- Base-year quantities of fuel demand or useful energy demand by sector, sub-sector, end-use, and devices;
- Base-year prices of all resources;
- Base-year costs, production, capital, O&M costs;
- Stockpile data, quantity of a resource removed in the base year; quantity of a resource at the end of the base year, fraction of stock to export;
- Resource reserves, annual resource capacities, additional resource throughout the planning periods;
- Energy processing efficiency, processing capacities, capacity factor, life expectancy of plant in the base year and future;
- Projection of final demand (which can optionally be obtained from ENPEP's DEMAND module);
- Projection of all fuel prices (domestic and imported fuels);
- Projection of all costs;
- Price regulation process, that is, price multiplier, price addition, maximum price, minimum prices, and chemical content of energy, emission factors for estimating pollution emissions in MPACTS. (This data is available in the database, but it can be modified by a user to reflect economy-specific conditions.)

5.1.3 Advantages of BALANCE

The first step in working with BALANCE is to design the energy network of the economy. The data is then entered, based on this designed network. By having the network, it creates a full understanding of the entire energy system which makes it easy to manipulate the scenario analysis, to add on more details of the energy technologies, or to modify the existing case for the future study.

The market-sharing algorithm technique allows for the simulation of market operation with multiple decision-makers. It offers an advantage over least-cost optimisation approaches that are suitable for simulating a single decision maker.

BALANCE allows not only price, but also non-price factors, such as convenience of use, technology related factors and government policies, to determine resource consumption in the economy. Therefore, energy requirements may be met by selecting fuels from several supply sources simultaneously rather than from a single source, as would be the case if fuel choice were based strictly on least cost. BALANCE thus has advantage over a linear optimisation approach by recognising that the "least cost" source of energy does not, in general, capture the entire market shares.

BALANCE has a flexibility that allows the user to make adjustments in the model, in order to control the results to some degree. This flexibility could be beneficial, in the case where the user wants to include a forecast from other sources with the result from the model. For example, the user can manipulate the model to control fuel mix of power generation to be consistent with the forecast from the utility, and let the model allocate other fuel supplies to meet the end-use demand.

BALANCE can be linked with other sub-modules of ENPEP. For example, a more detailed dispatch analysis can be conducted using ICRUS (Investigation of Cost and Reliability in Utility Systems) and a more detailed analysis of energy demand can be performed using MAED (Model for the Analysis of Energy Demand).

ENPEP can also be linked to other ANL models such as GTMax (Generation and Transmission Maximisation Model) to study complex electric utility's marketing and system operational issues, MCITOS (Multi Criteria Interval Trade-Offs System) to perform a mutli-criteria decision analysis, or APEX (Argonne Production, Expansion and Exchange Model for

Electrical Systems) to address various policy options that affect electric utilities.

BALANCE can project energy demand/supply for up to 75 time periods. Also, model calculation periods and model reporting periods need not be the same. The user can define any time interval to be the basis for model calculations (such as 1 year), but can report the results at other time intervals (such as every five years, or every ten years). This attribute benefits renewable energy characterisation since it enables one to capture time-dependent resource and technology factors more accurately.

The direct advantage concerning renewable energy component is that the model allows an estimate of annual supply in the form of a step function. This step function allows the user to model any physical limitation of the annual production of the resource, such as the upper limits on the annual amount of solar energy that can be used due to the amount of solar insoation, an upper limit on annual wood production due to the amount of land available for wood production, or the physical limitation of each source of resource supply.

Another advantage regarding the inclusion of renewable energy in the model is that special features in BALANCE that are used to control allocation of resources such as premium multiplier, price sensitivity, and lag adjustment can be applied to the case of renewable energy and make renewable energy have a fairer share in the allocation process.

5.1.4 Limitations of BALANCE

BALANCE is data intensive compared to the other models such as LEAP and MARKEL, thus requiring a significant effort for data collection before working with the model. The model is complicated, and not user friendly. Extensive training and experience are definitely required in order to work successfully with the model.

5.2 Long-Range Energy Alternatives Planning System (LEAP)

LEAP was developed by the Stockholm Environment Institute-Boston Center at the Tellus Institute, with support from the United Nations Environment Programme and various other organisations.

More than 200 government agencies, NGOs and academic organisations world wide use LEAP for a variety of tasks including, energy forecasting, greenhouse mitigation analysis, integrated resource planning, training and capacity building, the production of energy master plans, and energy scenario studies. LEAP has been applied at many spatial levels including local rural areas, large metropolitan cities, and at the national, regional and global level.

5.2.1 Model Structure

LEAP is an energy accounting framework. It contains a full energy system which enables consideration of both demand-side and supply-side technologies and accounts for total system impacts.

LEAP is structured as a series of integrated programs. There are four main program groups and five sub-programs:

- Energy Scenarios
- Demand
- Transformation
- Biomass
- Environment
- Evaluation
- Aggregation
- Environmental Data Base
- Fuel Chains

The Energy Scenarios programs are the main tools used to perform an integrated energy environment planning exercise in an area. The programs assist in developing current energy balances, projections of supply and demand trends, and scenarios representing the effects of energy policies, plans, and actions.

End-use consumption is calculated by the *Demand program*. Based on this demand estimate, the *Transformation program* simulates the conversion of primary energy resources to final fuel (for example, coal to electricity in power plants) to match supply to demand.

Optionally, the *Biomass program* can be used to examine in more detail the adequacy of, and impacts on, biomass resources, based on the need for biomass fuels and the land use changes taking place in an area.

The *Environment program* calculates the consequent environmental emissions based on the information contained in the Environmental Data Base.

The *Evaluation program* compares the economic (costs and benefits), physical (energy and resource usage), and environmental (emissions) impacts of alternative energy scenarios. The Aggregation program is a tool used to display multi-area results from analyses carried out in different geographical areas.

The Environmental Database can be used either as a stand-alone reference tool, or linked to the rest of LEAP to automatically calculate emissions and other environmental impacts of energy scenarios.

The Fuel Chains program is used to compare the total energy and environmental impacts of alternative fuels and technology choices per unit of energy or energy service delivered. For each end-use fuel and technology option, a “chain” is constructed which traces the energy inputs and environmental impacts for each upstream energy conversion stage.

5.2.2 Advantages of LEAP

LEAP is a simple model that does not require a long training period. The program is designed to be user-friendly with a detailed manual and on-line help. LEAP will be useful in cases where the analyst wishes to determine the energy and environmental impacts of proposed governmental policies where the initial technology projection has been predetermined.

LEAP has a feature allowing co-ordinated planning at more than one spatial level. For example, energy scenarios can be developed at the state or provincial level and then aggregated to the national level, or from the national level to the multinational or global level.

5.2.3 Limitations of LEAP

Due to the nature of the model, it cannot analyse fuel competitiveness between renewable energy and fossil fuels. The dispatch rule for the electricity module has to be specified. The default method is to dispatch in turn by merit order and run until the total electricity requirements are met. Using this method means that the optimum capacity factors of plants are known, which means an electric utility dispatch model has to be run first. The results from the run can then be entered in LEAP.

Another option of dispatching is to enter data describing a load curve. Plants will then be dispatched according to the merit orders defined for each plant. Each plant will be run up to its maximum capacity factor to meet the system load curve as well as the overall energy requirements within the module. This method does not allow for random outages during the year. All plants are assumed to be available at peak load time. Since in reality, only a proportion of plants will be available at any given time due to planned or forced plant maintenance, this method tends to overestimate the reserve margin in the peak load and underestimate it during the lowest load.

5.3 Market Allocation Program (MARKAL)

MARKAL was developed in 1978 in a joint effort by the Brookhaven National Laboratory (BNL) in the United States and the Kernforschungsanlage-Julich (KFA) in Germany for the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA). The primary objective was to assess the long-term role of new technologies in the energy systems of the 17 IEA member countries. Since that time the model has evolved and has been applied to a wide range of energy and environmental issues in many countries other than IEA member countries.

5.3.1 Model Structure

MARKAL is a linear-programming (LP) model of a generalised energy system. It is demand-driven for which feasible solutions are obtained only if all specified end-use demands for energy are satisfied for every time period. The end-use energy demand for each demand sector and for each time period are exogeneously forecast. The objective is to determine the optimum activity levels of processes that satisfy the constraints at a minimum cost. Examples of constraints in the model include availability of primary energy resources, production/use balances, electricity/heat peaking, availability of certain technologies, and upper bounds on pollution emissions. MARKEL is

MARKAL and MUSS are independent systems communicating by means of standard MS-DOS exchange files. MUSS is a relational database management system designed specifically to facilitate the MARKAL model use. MUSS oversees all aspects of working with MARKAL. It manages all the input data required by MARKAL, organises data sets into scenarios to foster sensitivity analyses, integrates seamlessly with the modelling system, and manages the results from model runs.

The elements of MARKAL simulate the flow of energy in various forms (energy carriers) from the sources of supply (import, export, mining, and stockpiling) through transformation systems (resource, process, conversion, and demand technologies) to the demand devices which satisfy the end-use demands.

The elements of an energy system in MARKAL are grouped as:

- *Energy Carriers*:
  the component that encompasses all the energy forms in the energy system,
- *End-Use Demands:*
  the component that comprises the demands for end-use energy services in the economy,
- *Demand Technologies*:
  all devices that consume energy carriers to meet energy demands,
- *Conversion Technologies*:
  all load-dependent plants that generate electricity or district heat or both,
- *Process Technologies*:
  all load-independent processes that convert one energy carrier to another,
- *Resource Technologies:*
  the means by which energy enters or leaves the energy system, other than end-use consumption,
- *Emissions*:
  the component that encompasses the environmental impacts of the energy system.

The data for the *Data Parameters* is determined by the user. MARKAL provides some 80 different *Data Parameters* for describing the characteristics of the energy system and the items within it. The *Results Parameters* are determined by a MARKAL model run. MARKAL provides some 220 different *Results Parameters* in its reporting of a model run result.

5.3.2 Data Requirements

MARKAL requires a moderate set of data. The data used in MARKAL is defined as either required data or valid data. If *required data* is not filled in by users, there are defaults (for example, technical efficiency of the demand technology is equal to 1, and investment cost is equal to 0). *Valid data* is optional. If valid data it is not filled in, the model will ignore that parameter. The following list is some of the required data:

- Technology data
- Fuel used and/or produced,
- Investment costs,
- Fixed and variable operating costs,
- Fuel costs,
- Technical characteristics, such as, conversion efficiency, energy efficiency of demand devices, and capacity and availability factors,
- Capital stock,
- Productive life of technology.
- Sources of primary energy

Primary energy may include any type of energy supply, for example, oil, gas, coal, biomass, etc. These sources are usually characterised by supply curves that allow the annual potential supply and extraction costs. The information required includes:

- Resource costs, such as, export, import, and extraction costs,
- Annual or cumulative limits on availability,
- Period of resource availability.
- Demand data

Demand is specified either in terms of energy requirement or of useful energy demand. Demand levels are determined from information such as the square footage of housing heated or vehicle miles traveled. End-use demands are specified exogenously for all time periods.

Environmental data
Environmental emissions can be calculated based on the source of a fuel (for example, CO2 emissions from oil imports) or on the technology used (for example, NOx emissions from road transport technologies). Environmental constraints may be introduced as a physical cap on pollution emissions.

5.3.3 Advantages of MARKAL

MARKAL benefits from a large user community which constantly makes additions to the basic modelling framework. Examples include major model changes such as the linkage with a macroeconomic model, and the addition of new functions such as stochastics and endogenous technology learning. These changes are documented in “info” text files distributed in the model program.

MARKAL can be used in conjunction with a macroeconomic model, such as MACRO, and thus allows interplay between the energy system and the economy, or with a partial equilibrium formulation, such as MICRO or MED, where demand levels are endogenously determined based upon price elasticities.

An inherit advantage of optimisation models is that they, by default, perform at least cost competition of fuel. This is particularly worthwhile in dispatching electric power plants where one wants to see the effects of fuel competition over the planning periods.

A marginal cost calculation is available as a standard output, making it easy to compare each supply option and technology directly within the model, as well as to observe the overall effects on the cost of emission reductions for various technology mixes and policies.

MARKAL can track materials, financial flows, employment or any other commodities that can be linearly tied to the activity (or capacity, investment, etc.) of the process.

MUSS provides extensive multi-case comparison graphic facilities to facilitate the task of analysing the results of runs. The most essential capability is to be able to graph the results of multiple cases (up to 10 cases) side by side using various plot types (such as, line, bar, and cumulative). MUSS can display both primal (such as capacity level) and dual (such as effect on the objective function of one more/less unit of capacity) on a single graph. MUSS can also plot those entries changing between runs, and the differences between runs and periods to facilitate multi-case analyses.

There are two particular useful overview graphing capabilities available in MUSS. The first is the CERI (Constant Emission Reduction Indicator) graph, which shows how the cost of the energy system changes as the emission levels are reduced. The second is the Contribution Reduction graph, which shows how a reduction target is reached, for example, switching from fossil fuel to renewable energy or nuclear, efficiency improvements, or lower demand levels.

MUSS includes a “data multiplier facility” to facilitate changing from the source data units to those used within MARKAL. However, the user must provide the conversion factor needed by the multiplier facility.

MUSS has on-line documentation which can be used for comments associated with a table. It can also record the source of table data or method of calculation. In addition, the system automatically tags modified rows with the date on which they were last changed.

MUSS has a function to print out input assumptions and all the information relating to a technology, demand sector, supply option, or a group of technologies used for the study in a simple documenting format for expert review.

MUSS draws network diagrams, called a Reference Energy System (RES), which provides the user with simplified graphics of the model’s system. RES indicates which fuels flow in and out of the various technologies in the system. The RES diagram is drawn according to the data found in the current scenario along with the base-case scenario. The RES can be viewed focusing either on a demand, a technology, or an energy carrier.

MUSS has a function called the “bluebook option”, which reorganizes/regroups the input tables so that input assumptions for various technologies or supply options can be examined and compared simultaneously.

MUSS provides an “Enduse Demand Calculation” module to forecast useful energy demand. It calculates future demand by applying basis (for example, in the case of residential space heating, number of households) and saturation values (for example, the percent of households needing heating) given for future periods to the historical technology levels for the first period.

5.3.4 Limitations of MARKAL

Due to the nature of LP, MARKAL always chooses the least cost solution. The energy service with the lowest cost will take the entire market, and the competitors with only slightly greater costs will be excluded. While in reality, factors other than price often affect decisions for fuel choices, these factors can only be addressed in MARKAL to a limited degree by means of technology-based discount rate.

MARKAL will calculate an energy balance based on the year specified, and interpolate linearly between the values found in the period before and the next period following the defined year. For example, if the data is listed for time period 1 (1990) and 3 (2010), the data for period 2 (2000) is interpolated linearly by MARKAL between the values in period 1 and 3. The use of multiple-year planning periods poses problems for renewable energy modeling in terms of resource characterisation and technology implementation since renewable energy technologies can have very short construction times. Such modularity related advantages of renewable energy are difficult to show in the multiple year planning context.

MARKAL does not contain a complete environmental database, as do the two other models under such as LEAP and ENPEP.

5.4 PRIMES

The development of the PRIMES energy system model has been supported by a series of research programmes of the European Commission. It has been also extensively used for DG Environment and has started to be used at government level in the EU.

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the European Union (EU) member states. The model determines the energy market equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use.

PRIMES provides scenarios for the energy system of the EU countries and accession and neighbouring countries based on Eurostat energy balances i.e. the data submitted by member countries.

5.4.1 Model Structure

PRIMES is a general purpose model. It is conceived for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon in 5 year intervals up to 40 years. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies.

The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

The model can support policy analysis in the following fields:

- standard energy policy issues: security of supply, strategy and costs;
- environmental issues;
- pricing policy, taxation, standards on technologies;
- new technologies and renewable sources;
- energy efficiency in the demand-side;
- alternative fuels;
- energy trade and EU energy provision;
- conversion decentralisation, electricity market liberalisation;
- policy issues regarding electricity generation, gas distribution and refineries;

A fundamental assumption in PRIMES is that producers and consumers both respond to changes in price. The factors determining the demand for and the supply of each fuel are analysed and represented, so they form the demand and/or supply behaviour of the agents. Through an iterative process, the model determines the economic equilibrium for each fuel market. Price-driven equilibrium is considered in all energy and environment markets, including Europe-wide clearing of oil and gas markets, as well as Europe-wide networks, such as the Europe-wide power grid and natural gas network.

Although behavioural and price driven, PRIMES simulates in detail the technology choice in energy demand and energy production. The model explicitly considers the existing stock of equipment, its normal decommissioning and the possibility for premature replacement. At any given point in time, the consumers or producer select the technology of the energy equipment on an economic basis and can be influenced by policy (taxes, subsidies, regulation) market conditions (tariffs etc.) and technology changes (including endogenous learning and progressive maturity on new technologies)

Due to the heterogeneity of the energy market no single methodology can adequately describe all demand, supply and conversion processes. On the other hand, the economic structure of the energy system itself facilitates its representation through largely separable individual units, each performing a number of individual functions.

Based on these principles, PRIMES is organised around a modular design representing in a different manner fuel supply, energy conversion and end-use of demand sectors. The individual modules vary in the depth of their structural representation.

The modularity feature allows each sector to be represented in the way considered appropriate, highlighting the particular issues important for the sector, including the most expedient regional structure. The electricity module covers the whole Europe, while representing chronological load curves and dispatching at the national level. The natural gas market also expands over the whole Europe. However, coal supply, refineries and demand operate at the national level. Furthermore, the modularity allows any single sector or group of sectors to be run independently for standalone analysis.

The model produces long-term (up to 2030) projections of:

- production, imports, conversion, consumption and prices of energy
- investments, technology choice and cost of policies investments, under given exogenous assumptions for:
- macroeconomic and financial factors;
- world energy markets,
- resources, technologies and costs;
- behavioural and technology choice characteristics of the different energy agents

The baseline scenario is the benchmark reflecting current policies against which the effects of additional policies can be evaluated.

As an energy system model can handle changes in the fuel mix. As an EU wide model, it can handle issues related to fuel and emissions trading among member states.

5.4.2 Data Input Requirements

The data that are necessary to calibrate the model for a base year (1995) and a country (all EU member-states) can be divided in the following categories.

- Macro-economic data that correspond to demographics national accounts, sectoral activity and income variables. These data usually apply to sectors.

- Structure of energy consumption along the above-described tree in the base year and structure of activity variables (production, dwellings, passenger-kilometres, etc.). Some indicators regarding specific energy consumption are also needed for calibration. The data bases MURE, IKARUS, ODYSSE and national sources have been used.

- Technical-economic data for technologies and sub-sectors (e.g. capital cost, unit efficiency, variable cost, lifetime, etc.). The basic source of data for energy consumption by sector and fuel is Eurostat (detailed energy balance sheets).

5.4.3 Limitations of the PRIMES

Full utilisation of the model requires results from other model runs including

POLES model (IEPE - world)
GEM-E3 model (NTUA - economic growth)
PRIMES-Refinery model (IFP - refineries)
PRIMES-Transport model (KUL – Transport sector)

A very large amount of detailed data describing both the energy markets and the individual energy technologies, such as the power generation sector, is required on both national and EC-wide levels.

6 INTERNATIONAL STANDARDS IN ENERGY PLANNING AND ANALYSIS.

On a global level integrated energy system analysis built in a modular structure has become the focus of developers of large energy system models in recent years to accommodate the needs of policy makers in terms of market liberalisation, sustainable development and climate mitigation analysis. The modular structure allows the models to be run either as full integrated models often with links to other large models and data bases or where the modules can be run as stand alone models at the technology, sector, national or regional level.

In the US and European Union energy policies have been enhanced by computer models as decision tools since the 1970s. As a result the application of energy planning and analysis tools as part of the policy decisions process is well established and far more advanced compared to that of the 12 Mediterranean countries in this study.

In the US the primary model used in policy decision making is the National Energy Modeling System (NEMS). This is a general equilibrium model of the interactions between the U.S. energy markets and the economy. The model achieves a supply-and-demand balance in the end-use demand regions, defined as the nine Census Divisions, by solving for the prices of each energy type so that the quantities producers are willing to supply equal the quantities consumers wish to consume. The system reflects market economics, industry structure, and energy policies and regulations that influence market behavior.

The European community over the past three decades has sponsored the development of numerous models as shown in Table 3 above. The primary models in use at the European Community policy level is PRIMES and POLES, both of which have evolved through European Community sponsored programmes. They have a high level of complexity and are powerful decision tools for policy development, which in part reflects the length of time they have been in development.

Globally other models which have come to the forefront for Energy Analysis and Planning are ENPEP, LEAP and MARKAL.

ENPEP is now in use in over 70 countries and is regarded as an international standard as an energy planning tool. More than 500 energy experts have been trained in the use of the entire ENPEP package or some of its modules during the international training courses organised by the IAEA in collaboration with Argonne's Decision and Information Sciences (DIS) Division. ENPEP has been introduced into 11 of the 12 Member countries. The IAEA has liaison officers in 8 of the 12 MP countries.

Included in the latest version of ENPEP as a module, is a windows based version of WASP (The Wien Automatic System Planning Package). WASP merits recognition as an international standard since the IAEA's most popular and long lived tool for electricity system planning and appears to be the most applied model in the 12 MP countries.

The primary objective of WASP is to determine the least-cost generating system expansion plan that adequately meets demand for electrical power while respecting user-specified constraints regarding the maximum number of thermal or hydroelectric units that can be added in a given year and the acceptable level of system reliability.

LEAP has also been introduced to 11 of the 12 Mediterranean countries. More than 200 Government agencies, NGOs and academic organisations world wide use LEAP for a variety of tasks including, energy forecasting, greenhouse mitigation analysis, integrated resource planning, training and capacity building, the production of energy master plans, and energy scenario studies. LEAP has been applied at many spatial levels including local rural areas, large metropolitan cities, and at the national, regional and global level.

MARKEL has only been introduced to one of the MP countries, Turkey but has a wide user community outside of the region. Over 70 teams in more than 35 counties around the world make use of the MARKAL family of energy/economy/environment models. The primary objective of developing MARKEL was to assess the long-term role of new technologies in the energy systems of the 17 IEA member countries. Since that time the model has evolved and has been applied to a wide range of energy and environmental issues in many countries other than IEA member countries.

The model has been used by some countries, notably the United Kingdom and the Netherlands, as a tool in the development of policy and priorities for energy research and Development. There are contracting parties from 19 countries (Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Italy, Japan, Korea, the Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States) and the European Commission.

In terms of advancing the standards in energy analysis and planning in the Mediterranean region towards international standards, constraints are likely to be encountered in terms of data availability. The energy system models in use globally such as PRIMES, NEMS and ENPEP are large sophisticated models whose full utilisation requires linking to large databases and the running of other models to provide exogenous variables. Initial surveys of users in the Mediterranean countries have found that some model runs have not always been successful in that they have not produced feasible solutions the causes of which may be lack of data availability and or training.

7 CONCLUSIONS

- The development of energy analysis and planning models have closely matched the emphasis on energy policies over the past three decades which are now dominated by market reform, sustainable development and global climate change.

- With the introduction of market reform in the Mediterranean countries optimisation planning and analysis will be increasingly utilised by investors, while energy analysis and planning by governmental agencies and NGO's can be expected to focus on sustainable development[1] and climate mitigation analysis.

- The models identified as in use in the 12 Mediterranean countries are ENPEP, LEAP, MARKEL, WASP and PRIMES. Some of the models are only partially used, such as for climatic mitigation analysis, demand forecasting and or optimisation of electricity generation.

- Each of the models are large and sophisticated and require significant amounts data input and training.

- All the energy system modelling approaches are similar in that they are essentially quantitative and use mathematical formulations and equations whose parameters can be econometrically estimated or which consist of engineering parameters. Each energy model has advantages and disadvantages that users have to trade off.

- Some of the energy system models and tools available and in use in the Mediterranean countries differ in their approach to achieving a energy system balance i.e

    - ENPEP is a general equilibrium model which finds a set of prices and quantities that satisfy all equations and inequalities to balance supply and demand. ENPEP includes non price factors in its energy system balance including

    - LEAP is an energy accounting framework. It contains a full energy system which enables consideration of both demand-side and supply-side technologies and accounts for total system impacts.

    - MARKAL is a linear-programming (LP) model of a generalised energy system. The end-use energy demand for each demand sector and for each time period must be input into the model. Due to the nature of linear programming MARKEL always selects the least cost option and ignores non price factors.

    - PRIMES is a price-driven market and behaviour-oriented General Equilibrium Model. The factors determining the demand for and the supply of each fuel are analysed and represented, so they form the demand and/or supply behaviour of the agents. Through an iterative process, the model determines the economic equilibrium for each fuel market. The model therefore operates under perfect foresight of demand for fuels.

- The most appropriate energy planning models/tools for each of the 12 Mediterranean countries will be influenced by the level of primary energy supplies, fuel chain in each country and prevailing energy policies.

- The application of energy planning and analysis tools as part of the policy decisions process is as well established in the EU and US and more advanced compared to that of

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[1] With the introduction of free market theoretically there is no need for optimisation of generation options previously carried out by state monopolies, but demand supply balancing is needed for security of supply, a function of the system operator.

the 12 Mediterranean countries in this study. The most widely used models in the MP countries are ENPEP and LEAP.

- In terms of advancing the standards in energy analysis and planning in the Mediterranean region towards international standards, constraints are likely to be encountered in terms of data availability. The energy system models in use globally such as PRIMES, NEMS and ENPEP are large sophisticated models whose full utilisation requires linking to large databases and the running of other models to provide exogenous variables.