UNITED NATIONS

E

ECONOMIC AND SOCIAL COUNCIL

Distr.
LIMITED
E/ESCWA/ENR/2001/WG.2/6
4 October 2001
ORIGINAL: ENGLISH

Economic and Social Commission for Western Asia

Expert Group Meeting on Energy for Sustainable Development
in ESCWA Member States: the Efficient Use of Energy and
Greenhouse Gas Abatement
Beirut, 8-11 October 2001

ENERGY CONSERVATION THROUGH THE IMPLEMENTATION OF A NATIONAL ENERGY MODELING SYSTEM (NEMS)

by

Chafic Abisaid

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1. Foreword

The Energy, Natural Resources & Environmental Division of the ESCWA, within the framework of its program of work on Energy for Sustainable Development in the ESCWA Member States is organizing this meeting to exchange views and experiences related to the development of sustainable energy strategies and systems Beirut, 8-11 October 2001, under the heading: "*The Efficient Use of Energy & Greenhouse Gas Abatement*", with emphasis, among other topics, on the need for, and experience in developing "*Policy measures and technical options for the efficient use of energy in different sectors*".

In line with the meeting heading and the emphasis stressed, my presentation is entitled: "*Energy Conservation through the Implementation of a National Energy Modeling System (NEMS).* The title may indicate that the topic of this presentation digresses outside the scope of the present meeting. In fact, through the sequence of my presentation, I shall attempt to confirm that an "Energy Modeling System (EMS)", in particular a national one, is a prerequisite to a successful sustainable energy strategy and its efficient use. The Lebanese case shall eventually be analyzed as a typical example.

2. Definition of an Energy Modeling System (EMS)

The EMS is a computer-based, energy-economy modeling system of energy markets in a country. The model projects the production (if any), imports, conversion, consumption and prices of energy, subject to assumptions on macro-economic and financial factors, world/ regional energy markets, resource availabilityand costs, technological choice criteria, cost and performance characteristics of energy technologies and local demographic conditions.

The EMS objective is to assist governments develop short and long term energy policies and evaluate their impacts , both, on the economy and development of the country .

3. Sustainable Development

The recent concept, stressing the harmonization between economic growth and environmental preservation [1], features sustainable development as:

a- the issue of "distributed equity", both within the same generation (inter-generation equity) and between different generations (intra-generation equity);
b- an economic-ecological integration in terms of resource use and pollution emissions.

4. Sustainable Energy

Energy is central to achieving the interrelated economic, social and environmental aims of sustainable human development. Sustainable patterns of energy production, distribution and use are crucial to continue improvement to the quality of life [2].

The effective utilization of energy as a tool for sustainable development shows that, *in addition* to the promotion of energy efficiency & renewable energies and the use of advanced technologies, analytical background and scientific information should be be available for decision makers at all levels.

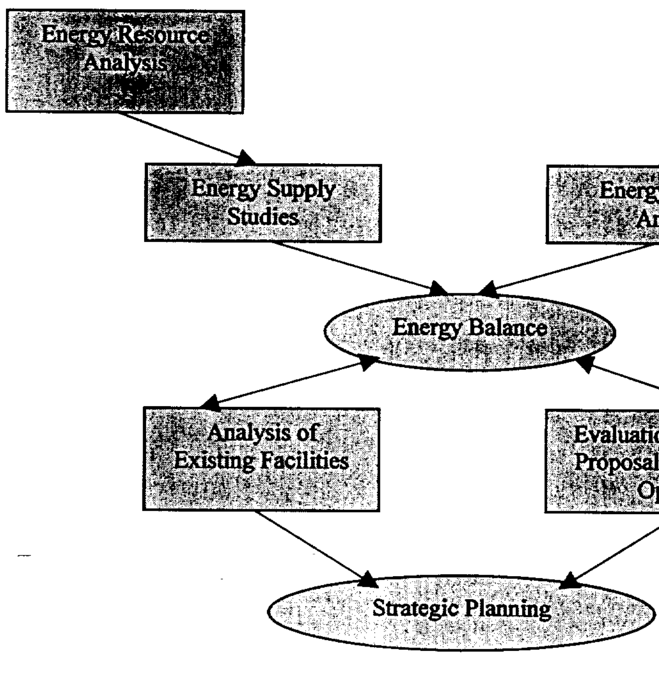
In the developed countries, extensive information is normally available. Appropriate plans and strategies can be easily prepared and evaluated in the light of such information. Such analysis give the decision makers an accurate view of the consequences for the entire system of modifications that might take place. In contrast, few developing countries have ready access to the information required. The boundaries and nature of the impact statements generated by the modification or the creation of a system would not allow the decision makers to evaluate accurate short or longer terms effects.

Therefore, an essential step for sound planning is to collect, analyze and supply information on the interrelations of the relevant variables with which planners and decision makers need to deal, in order to give them a view of the dynamics of the system and help them develop the appropriate changes / strategies [3].

Keeping in line with the sustainable energy concept, the whole system is a chain interrelated, interactive and undergoing constant change. The response to market and technological changes of all assets on the national balance sheet must be assessed in sufficient time for the appropriate action to be taken.

5. Energy Market & Macro-Economy

As previously stated, the area of interest to many decision makers nowadays is on the feedback effects from the energy market to the macro-economy. Even more crucial is the impact on economic activity of an increase in the price of oil since oil is a major contributor to the energy cost. The initial effect of such an increase is felt in the economy directly from the price of oil to the level of domestic prices. Another linkage between the energy market and the macro economy, which operates through the supply side of the system, is fuel availability. Any production function in the macro-model should take into consideration energy as a major driving force. In fact, *capital, labor and energy* become the basic inputs in the production process that define the potential output of the economy. Figure1 below shows the flowchart of a typical organization of an energy model.



6. National Energy Strategy

Energy has a major impact on the national macro-economy, sustainable development, environmental issues, development of new technologies, etc. The energy market affects the basic activities of a society, namely:

- Production of the various sectors;
- Interactions between the supply side and the end use side;
- Fuel availability;
- Fuel prices;
- Energy diversification;
- Environmental impacts;
- National economic growth, etc.

It is clear therefore that there is a need for a ***National Energy Strategy***, to satisfy and optimize the ***Energy supply-demand balance*** of the various sectors: Industrial, commercial, agricultural, transportation, domestic, etc.

7. Energy Model Functions

As a tool for energy policy analysis, a comprehensive "Energy Modeling System" must be evolved with the following functions in mind:

- Provide a modeling methodology for a supply/ conversion/ demand equilibrium, with quantities and prices, of the various types of energy, being computed by modules that represent production, raw material transportation, conversion, final product transportation and end-use energy consumption.
- Study specifications among Fuel supply conversion and consumption sectors, between the domestic energy system and domestic economy, both at present and as expected in the future.
- Capture important interrelationships in energy markets, in order to simulate the response of the entire energy system to changes in market conditions.

8. Modeling System Background

The enterprise of constructing and using a comprehensive computer-based model of the U.S. Energy System. was initiated in the Federal Energy Administration in 1974 [4]. The motivation for developing such a model, at that time, was the issue of energy supply sufficiently prompted by the Arab oil embargo in the Fall of 1973. The energy policy analysis debate has since continued.

In conjunction with policy analysis needs, a comprehensive energy modeling system has been continuously improved and expanded into a long term energy analysis package, with additional modules to simulate most energy related aspects. This package solved for energy/demand equilibrium, with prices and quantities of the various types of energy being computed by modules.

The latest improvement of U.S. NEMS incorporates an international component to directly account for the interaction between the domestic energy market and the world oil market.

Structural details was added to U.S. NEMS, allowing for more accurate representation of current policy analysis issues and emerging market characteristics. In addition, flexibility is achieved through use of an improved centralized database design that provides greater storage and control over prices and demand variables related to the future.

9. Energy Model Components

The energy model components consist of the following three sections:

- The Supply components
- The conversion components
- The demand components

Each component is composed of several modules, which in turn, consist of several submodules that represent the types of applications. At the same time, each submodule may be solved independently of the rest. Interactions among the submodules occur indirectly through each submodule's interaction with other NEMS modules. To illustrate, consider the following sections and their modules, each with its submodules:

- The supply section has the oil & gas supply module, the renewable fuels module, etc.
- The conversion section has the electricity module, the petroleum module, etc.
- The demand section has the residential, commercial, industrial, agricultural, transportation modules, etc.

9.1. The Supply Components

9.1.1. Oil and Gas Supply Module

The oil and gas supply module consists of a series of processes that project the availability of:

- Domestic crude oil and dry natural gas production.
- Quality crude oil/refined oil.
- Quality pipeline – gas.
- Quality liquefied natural gas.

Quality issue is concerned with locally produced/refined or imported product. submodules for domestic oil and gas supply and for natural gas imports/exports have been developed. International gas trade is determined in part by scenario-dependent, non-economic factors. Crude oil is transported in its ready to use form or to refineries for conversion and blending into refined petroleum products.

9.1.2. Renewable Fuels Module

The renewable fuels module consists of several sections that represent the various types of renewable energy. Since most renewables (hydraulic,wind, solar,...) can be used to generate electricity, the interaction with the electricity market module and its various sections is important for modeling grid-connected and stand-alone renewable-electric applications. A short description of each main submodule is given in the following subsections.

9.1.2.1. Hydroelectric resources

The hydroelectric section provides currently available and planned regional hydropower capacity and capacity factors for conventional hydroelectric facilities. This plant information is supplied by aggregating the responses of utility and non-utility power producer, to annual power plant surveys. The emphasis of the section is on planned hydroelectric capacity additions and reductions. Since hydropower operating and maintenance costs are assumed to be the lowest of any major generating technology and hydropower produces, virtually no air pollution, all available hydroelectric capacity is to be given priority.

9.1.2.2. Wind-Electric resources

The wind electric submodule projects the availability of wind resources as well as the cost and performance of wind turbine generators. This information is passed to NEMS so that wind turbines can be built and dispatched in competition with other electricity generating technologies. The wind turbine data may be expressed in the form of energy supply curves, which provide the maximum amount of turbine generating capacity that could be installed, given the available land area, wind speed, and capacity factor.

9.1.2.3. Solar-Electric resources

The solar-electric submodule models, both solar-photovoltaic and thermal-electric installations. Solar electric generators constructed by a utility or independent power producers (IPP's) will be considered as generators. The solar-electric energy's intermittent nature and regionality must be taken into consideration. Competitive parameters (capital costs, capacity factors, fixed and variable operation and maintenance costs, etc.) against other generating technologies are analyzed in models.

9.1.2.4. Other Renewable Energy Submodules

Other resources might include the use of biomass, especially wood, for the purpose of generating electricity and satisfying certain applications not requiring electricity. Biofuels (Ethanol) may be another source. Municipal solid waste producing energy (Methane gas, etc) by incineration for heating and electricity generation may be a third source. Interactions among these submodules occur indirectly through each submodule's interaction with other NEMS modules.

9.2. Conversion Components

9.2.1. The Electricity Module

The electricity market module represents the generation, transmission, and pricing of electricity, subject to delivered prices for petroleum products, natural gas, and synthetic fuels; the cost of centralized generation from renewable fuels; macroeconomic variables for costs of capital and domestic investment; and electricity load shapes and demand. The sections consist of capacity planning, fuel dispatching, finance and pricing, and load and demand-side management, in conjunction with the demand modules. Non-utility generation from co-generators and other facilities, whose primary business is not electricity generation, can be represented in the demand and fuel supply modules. All other non-utility generation can also be represented in the electricity market module .

9.2.1.1. Electricity Capacity Planning Submodule

The electricity capacity planning section determines how best to meet expected growth in electricity demand, given available resources, expected load curves, expected demands and fuel prices, environmental constraints, and costs for utility and non-utility technologies. When it is decided that building new capacity is the best alternative for meeting some future increase in demand, then the timing of the demand increase, the expected utilization of the new capacity, and the construction and operating costs of various technologies primarily determine what technology is chosen. The ownership of the facility (utility or non-utility) influences time decision, because the capital costs differ according to the ownership and corresponding capital structure of the facility.

9.2.1.2. Electricity Fuel Dispatch Submodule

Given available capacity, firm purchased-power agreement, fuel prices, and load curves, the electricity fuel dispatch section solves for generation facility utilization and economy power exchanges to satisfy a demand that varies by time and region. The section uses merit order dispatching that is, utility, independent power producer, and small power producer plants are dispatched until demand is met. However, hydroelectric plants and other intermittent , renewable based technologies are exceptions to merit order dispatch.

9.2.1.3. Emission Submodule

The energy market module tracks emission levels for sulfur dioxide (SO_2), nitrogen oxides (NO,), carbon dioxide (CO2), carbon (C), carbon monoxide (CO), and volatile organic compounds (VOCs). Facility development, retrofitting, and dispatch are constrained to comply with the pollution constraints.

9.2.1.4. Other Electicity Market Submodules

Other electricity market submodules may be added, depending on each country's electric system needs. An electricity finance & pricing submodule and/or load and demand-side management submodule are possible additional submodules.

9.2.2 Petroleum Market Module

The Petroleum Market Module represents the pricing of petroleum products, crude oil and product import activity in conjunction with the international energy module, and domestic refinery operations, subject to the demand for petroleum products, the costs of investments, and the domestic production (if any) of crude oil and natural gas liquids. The Petroleum Market Module chooses a mix of refinery operations that minimizes the costs of meeting demand. Crude oil and petroleum products import quantities are chosen as part of the process of minimizing costs and emissions.

9.3. Demand Components

9.31. Residential Demand Module

The residential demand module forecasts fuel consumption in the residential sector for different housing types, and for several categories of fuel. This module provides forecasts of residential energy prices and housing starts, which are used to develop forecasts of energy consumption for each of the fuel types, as well as the emissions of a variety of pollutants generated by residential energy use.The effect on consumption of the replacement of more efficient housing equipments and appliances may be tested and tabulated in the form of submodules.

9.3.2. Commercial Demand Module

The commercial demand module forecasts the consumption of commercial sector fuels and electricity by building types and non-building uses of energy and by category of end use, subject to delivered prices of energy, time availability of sources of energy, and macroeconomic variables representing gross domestic product, employment, interest rates, and floor-space construction.Various submodules have been developed from the commercial demand module, related mainly to energy service demand and equipments choice.

9.3.3. Industrial Demand Module

The industrial demand module forecasts the consumption of fuels and electricity for heat and power for the energy-intensive industries. This includes the direct use of renewable energy, subject to delivered prices of energy and macroeconomic variables representing the value of output for each industry. The module includes industrial co-generation of electricity that is either used in the industrial sector or sold to electric utilities.Each industry may be modeled within three separate , but interrelated components: Buildings, boilers /steam / co-generation and process / assembly submodules . The influence of energy prices on industrial energy consumption are to be modeled in energy-intensive industries .

9.3.4. Agricultural Demand Module

The agricultural demand module forecasts the consumption of fuels and electricity for heat and power and for feedstock and raw material at the basic process level.

9.35. Transportation Demand Module

The Transportation Demand Module forecasts the consumption of transportation sector fuels by transportation mode, including the use of renewables and alternative fuels, subject to delivered prices of energy fuels and macroeconomic variables, including disposable personal income, gross domestic product, level of imports and exports, industrial output, new car and light truck sales, and population . Many submodules have been developed namely, fuel economy submodule, alternative-fuel vehicle submodule , various vehicle types modules, vehicle emission submodules and others .

9.4. Integrating Module

To supervise the entire NEMS process, the *Integrating Module* executes the demand, conversion, and supply modules until it achieves an economic equilibrium of supply and demand in all the consuming and producing sectors. The integrating framework incorporates interfaces to the macroeconomic module, and international / regional module, exchanging information between them and the domestic energy modules.

9.5. Macroeconomic Activity Module

The *Macroeconomic Activity Module* provides forecasts of economic variables to the energy modules within NEMS, and forecasts the impacts on the aggregate economy of changes in the energy market conditions. In particular, it provides variables that drive other parts of NEMS, including interest rates, final demands for goods and services, and disposable income. The inter-industry section calculates the industrial output needed to satisfy, the final demands from the national section. The industrial and transportation demand modules in the NEMS, use the levels of industrial output to calculate energy consumption in these sectors. These values will be later transformed into appropriate regional values in the Regional Section.

The sequence of interactions in the Macroeconomic Activity Module can be summarized as follows: The energy supply and demand modules of NEMS determine the reaction of energy prices to changes in events or policies. These energy price effects are passed to the national economy section (submodule), which is projected to react to the altered energy price paths. The altered macro-economic final demands are in turn passed to the inter-industry section, which calculates their effect on inter-industry activity. The altered inter-industry projections are then passed back to other NEMS modules, and the system iterates until convergence is achieved.

Macroeconomic activity module outputs include measures of macroeconomic performance and manufacturing and non-manufacturing sector production activities

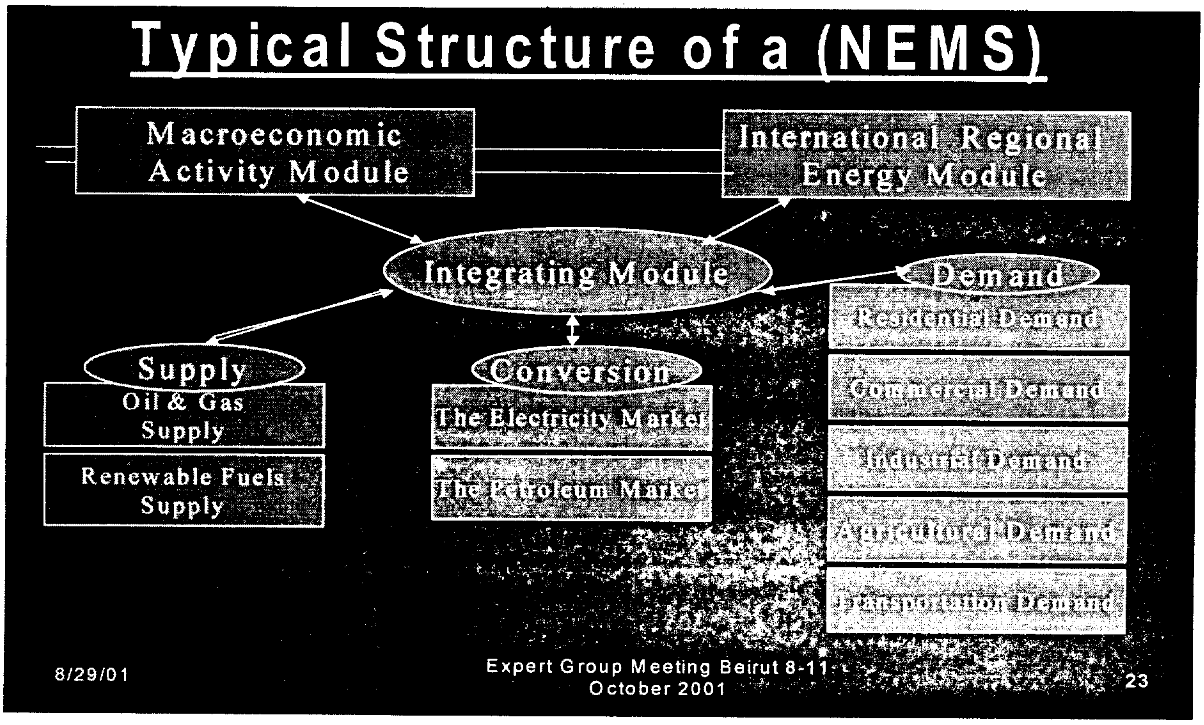
9.6. International/Regional Energy Module

The International/Regional Enrgy Module calculates the average price of imported crude oil/ oil / gas and provides supply curves for major grades for import . In addtion, it calculates the shifts in these supply curves as a result of variations of world prices and local economic conditions .

9.7. National submodule

The National section ressponds to two sets of information: energy prices at the wholesale and retail and exogenously specified information on labor force growth and productivity . The energy supply and demand modules determine the reaction of energy prices to changes in events or policies .These energy price effects are passed to the national section, where the economic system reacts to the altered energy price paths . the altered macroeconomic variables are then passed back to the other modules and the system iterates until convergence is reached.

Figure 2 below is a typical structure of a national energy modeling system (NEMS).



10. Energy Model For Lebanon (Eml)

10.1. Justification

The recent merging of the Ministry of Hydro-Electric Resources and the Ministry of Petroleum has resulted in the long awaited *Ministry of Energy and Water (MEW)* responsible for the whole energy sector. Unfortunately, Lebanon does not have, till now, an energy strategy nor does it have the necessary tools to help the Government define one. This is because prior to *MEW*, the diverse responsibilities in this sector were fragmented among the various ministries dealing with the different aspects of the energy sector.

Since Lebanon imports about 98% of its energy needs, the energy bill of the country contributes to a large proportion of the Government expenditures and debt. Therefore, it is important that the Ministry acquires a macro-economic energy model that will provide the necessary platform to develop strategic planning aiming at satisfying and optimizing the energy supply-demand balance while ensuring that all relevant Government policies reflect positively on national economy and infrastructure develop

The ongoing debate on a number of energy issues supports an energy model. Such energy issues include, but are not restricted to, the following:

- The Government-plan to import natural gas from Syria and Egypt to support a cleaner electricity generation industry.
- The Government-plan to eventually import liquid natural gas (LNG) through the sea .
- The Government tendency to favor the use of unleaded fuel in transport and to impose a tax on users of leaded fuel.
- The Government debate on whether diesel fuel should or should not be used in the transport sector.
- The Government concern on improving energy efficiency in the industrial and commercial

sectors.
- The Government concern on the need of reducing its expenditure on fuel.
- The need for close coordination between government and utilities departments, in particular in feasibility studies and planning.

We have witnessed repeatedly, UNDP, European Commission, World Bank, or Government projects under preparation or even implementation charged with the same tasks (partially or fully) and working unknowingly on similar deliverables for lack of coordination and coherent planning among the various government departments .

Other examples of energy topics that reflect the expected scope of present and future government policy -all of which can be addressed by an Energy Model for Lebanon (EML)-include the following:

- Impacts of energy tax policies on the Lebanese economy and energy system.
- Changes in the Lebanese economy and energy system that could result from emissions taxes.
- Effects of specific policies, such as mandatory appliance efficiency and building shell standards, on energy consumption.
- Response of the electric utility industry to limits on SO_2 emissions.
- Impacts of new technologies on consumption and production patterns and greenhouse gas emissions.

10.2. Energy Model Functions

The EML ought to be formulated with the following functions in mind:

- To provide sufficient modeling detail to support a broad range of policy analysis.
- To capture the important interrelationships in Lebanese energy markets in order to simulate the response of the entire energy system to changes in market conditions.

The EML is to be built to support energy policy analysis and to serve as an important resource for the development and analysis of the impacts of alternative energy policies on key Lebanese markets and economic growth.

As a tool for policy analysis, EML should simulate those aspects of the energy system to which policy initiatives will be most likely directed. For example, environmental issues related to energy production and consumption. In addition to environmental concerns, EML can be used to analyze the effects of existing government regulations and proposed regulatory reforms related to energy import, production and use. For example, EML can be used to study the following:

- Interactions among the energy fuel supply, conversion, and consumption sectors.
- Interactions between the domestic energy system and the domestic economy.
- Interactions between current import and consumption decisions and expectations about the future.

10.3. Tasks of a typical (EML)

To achieve a fully operational and computerized energy model for Lebanon:

Task 1. Develop a baseline characterizing the status of the existing energy sector, namely :

- Identify the critical energy consuming sectors in Lebanon
- Identify the sources of energy supplies
- Characterize the energy status in the various sectors
- Establish the status of the macro-economic activities in Lebanon
- Analyze the collected information in the context of the Lebanese economy

Task 2. Develop energy sector indices for the energy sub-sectors.

Task 3. Perform a baseline energy study in Lebanon and develop an energy balance for the country.

Task 4. Analyze the status of existing facilities (refineries, fuel storage, generating stations, other energy conversion mechanism).

Task 5. Design a framework for modeling the energy sector in Lebanon based on the results from Tasks 1 thru 4.

Task 6. Validate the data and determine the coefficients and parameters necessary to establish the link between energy and economic activities.

Task 7. Populate the various modules and sub-modules of the energy model with the baseline data described in the previous tasks.

Task 8. Provide the necessary techno-economic methodologies that illustrate the usage of the energy model in developing short, medium and long–term energy policies.

11. Conclusions

Based on our updated knowledge of the current status, needs and requirements of the concept of "*Sustainable Energy*", as well as the needs and requirements of a *modern ministry of energy,* a national macro-economic energy model initiates a country into sustainable development and help key decision makers to take the right decisions concerning energy issues.

We believe that the outcomes of such a study, if implemented, will help the ministry of energy, to enforce its leading role in the national economy and the country as the provider of reliable analytical information regarding the production, imports, conversion, consumption and prices of energy, subject to assumptions on macro-economic and financial factors, world / regional energy markets, resource availability and costs, technologies and local demographic conditions .

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September 12, 2001

Chafic ABISAID