Japan International Cooperation Agency (JICA)

The Organization for Energy Planning,
The Arab Republic of Egypt

THE STUDY
ON
BUILDING ENERGY-ECONOMIC MODEL
FOR
THE ARAB REPUBLIC OF EGYPT

FINAL REPORT
Summary

January, 2001

The Institute of Energy Economics, Japan (IEEJ)

The Study on Building Energy-Economic Model for The Arab Republic of Egypt

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List of Abbreviations

CAIP	The Cairo Air Improvement Project
CAPMAS	Central Agency for Public Mobilization and Statistics
EEA	Egyptian Electricity Authority
EEAA	Egyptian Environmental Affaires Agency
EGPC	Egyptian General Petroleum Corporation
ERSAP	Economic Reform and Structural Adjustment Program
FEI	Federation of Egyptian Industries
GOFI	General Organization For Industrialization
IDSC	The Cabinet Information and Decision Support Center
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
MOI	Ministry of Industry
MOP	Ministry of Planning
NREA	New and Renewable Energy Authority
OEP	The Organization for Energy Planning
WB	World Bank

1. Preface

1.1 Objectives and Targets of the Study

(1) Objectives

The objectives of the Study are to develop Energy-Economic models (short-term forecasting-simulation models) for Egypt to evaluate the impact of public energy policies on its economy, and to transfer the technology for building and operating of these models. The models are expected to be a basis for national energy planning, and to work toward a comprehensive plan for energy/economic development with targets to be met by the year 2005/06.

(2) Targets

According to the S/W and M/M signed between JICA and OEP on the 19th of May 1999, the major policy issues to be analyzed are summarized as shown in Table 1.1.1. These policy issues are also targets of our outputs by energy economic model.

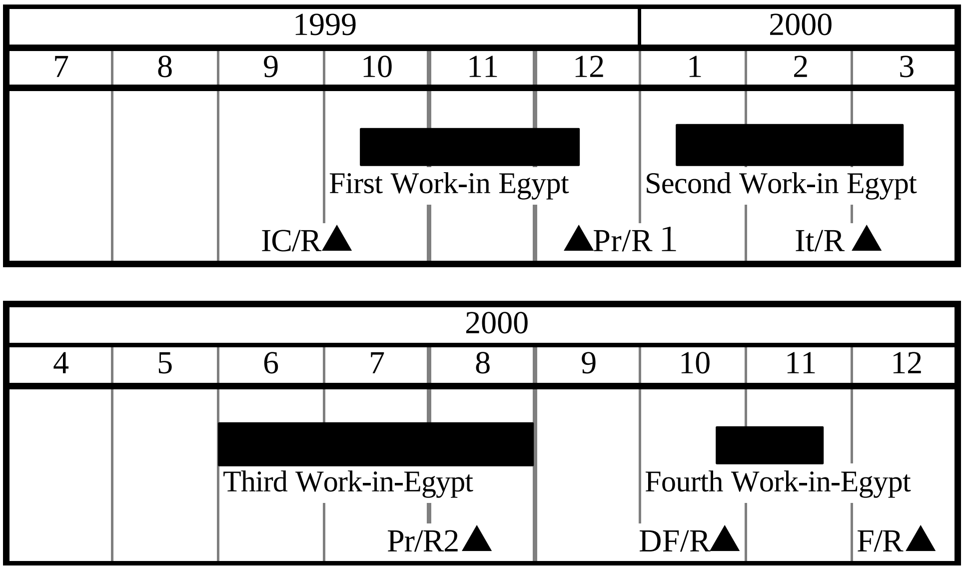
Table 1.1.1 Main Policy Issues to be Analyzed

No	Policy issues	Analysis items
1	Energy pricing	a) Impact of rising domestic energy prices on demand pattern and economic growth (GDP) b) Impact of changes in world oil price on Egyptian economy c) Effect of ERSAP policy measures on domestic energy sector
2	Energy efficiency and environmental impact	a) Evaluation of technical change in energy production and consumption on production activities and economy b) Energy policy – efficiency interaction c) Air pollution and GHGs abatement measures.
3	Energy substitution	a) Impact of introduction of oil alternative energy resources on energy and socioeconomic indicators b) Effect of energy policies concerning natural gas and specific oil products c) Role of new and renewable energy resources in energy mix
4	Energy demand	a) Energy demand by scenario (economic policy) b) Energy for supplying fresh water (energy demand for desalination plants) c) The most advantageous energy mix for socioeconomic development

1.2 Study Schedule and Work-in-Egypt

The Study is scheduled for 15 months, between October 1999 and December 2000. Figure 1.2.1 shows the overall work steps in Egypt.

Figure 1.2.1 Flow Chart of the Study Schedule



(Note)	IC/R : Inception Report	Pr/R1: Progress Report 1
	It/R : Interim Report	Pr/R2: Progress Report 2
	DF/R: Draft Final Report	F/R : Final Report

(1) First Work-in-Egypt

The main tasks of the first work-in-Egypt (for two months, Ocober 17 – December 14, 1999) were 1) to explain and discuss the Inception Report, 2) to collect and review the exsisting information and data after the confirmation of study direction, 3) to analyze the current societal, economical and energy situation, and 4) to discuss the framework of each model. Also, the workshop for building and handling of the energy-economic model was held. The study results of this stage were summarized in the Progress Report 1.

(2) Second Work-in-Egypt

In this second work-in-Egypt (for two months, January 15 – March 14, 2000), a database creation and energy-economic model building were tried. During the work, the Study Team also collected necessary data for the designs/development of models and database, and data/information for the analyses of energy supply-demand structure. The framework of models and database were completed, and the analyzed results were summarized in Interim Report. Workshop was held in this stage. The study results of this stage were summarized in the Interm Report.

(3) Third Work-in-Egypt

In the third work-in-Egypt (for three months, June 6 - September 1), model building, simulation of models, making of manuals and the technology transfer concerning model building and operation are carried out. Technology transfer was especially stressed in this stage. Especially two month technology transfer program was carried out. The study results of this stage were summarized in the Progress Report 2.

(4) Forth Work-in-Egypt

In the forth work-in-Egypt (for one month, October 23 – November 21), the Study Team submitted Draft Final Report and held the technology transfer seminar, which was held to increase mutual understanding concerning methodologies of model building and to expand the results to Egyptian public.

1.3 Technology Transfer

(1) First Work-in-Egypt

A one-week-workshop for model building concept was preceded with materials prepared in advance, and the contents were provided increase preliminary understanding and common recognition concerning methodologies of model building. Table 1.3.1 shows the program description of the workshop for energy-economic model building concept.

Table 1.3.1 Program of Workshop for Model Building

Date	Time	Program
Oct. 31 (Sun)	9:00 –15:00	Introduction to Econometrics and Simple E
Nov. 1 (Mon)	9:00 –15:00	Introduction to Macroeconomic Models
Nov. 2 (Tue)	9:00 –15:00	Introduction to Energy Economics
Nov. 3 (Wed)	9:00 –15:00	Introduction to Energy Demand Forecasting Model Building
Nov. 4 (Thu)	9:00 –15:00	Introduction to LP Methods and LP Model Building

(2) Second Work-in-Egypt

Table 1.3.2 shows the program description of the workshop.

Table 1.3.2 Program of Workshop for Model Building

Date	Time	Program
Feb. 9 (Wed)	10:00 –14:00	Energy Flow & Energy Balance Table
		Concept of Macroeconomic Model
Feb. 10 (Thu)	10:00 –14:00	Results of Factor Analysis

		Framework of Energy Supply Planning Model
Feb. 21 (Mon)	1o:00 –15:00	Practice of Macroeconomic Model
Feb. 22 (Tue)	10:00 –15:00	Practice of Macroeconomic Model Explanation of Energy Demand Forecasting Model
Feb. 23 (Wed)	10:00 –15:00	Explanation of Energy Supply Planning Model
Feb. 24 (Thu)	10:00 –11:30	Practice of Energy Demand Forecasting Model

(3) Third Work-in-Egypt

The framework of tchnology transfer procedure focussed on hand in hand computer practice according to M/M, signed between OEP and JICA Study Team on the 12th of March 2000. The contents of the technology transfer include 1) the theories and concepts underlying individual models, 2) the tools and methods of model building, 3) the technique of building the Energy-Economic model, 4) the energy databases and the database development tool, and 5) the model and its maintenance.

Lecture and practice were given to allocated counterparts of OEP (macroeconomic group, energy demand forecasting group, energy supply planning group and database group) during seven weeks around beginning half of the third work-in-Egypt. In general, model buildings for macroeconomic and energy demand forecasting models are based on econometric method, and model building for energy supply model are based on optimization method along with the knowledge of linear programming and energy sector. Taking into account the involvement of these two different methods, two teams were organized. One is the team of econometrics whose principal tool is "Simple-E." The team comprises of macroeconomics and energy demand forecasting groups. The other team is the engineering team whose principal tool is LP. The team comprises of energy supply planning and database groups.

Table 1.3.3 Curriculum for Technology Transfer

	Macroeconomic Model	Energy Demand Forecasting Model	Energy Supply Planning Model
1st week	Simple-E	Code name Agriculture sector	Guidance Coal flow
2nd week	Basic practice	Agriculture sector Industrial sector	Coal flow Gas flow
3rd week	Basic study	Industrial sector Residential/Commercial	Gas flow
4th week	Applied practice	Transportation sector Non-energy use	Total flow of energy system
5th	Test of model	Simulation	Total flow of energy system

week		Conversion sector	
6th week	Simulation	Simulation Electricity sector	Simulation Prices & cost
7th week	Simulation	Total flow of model	Simulation

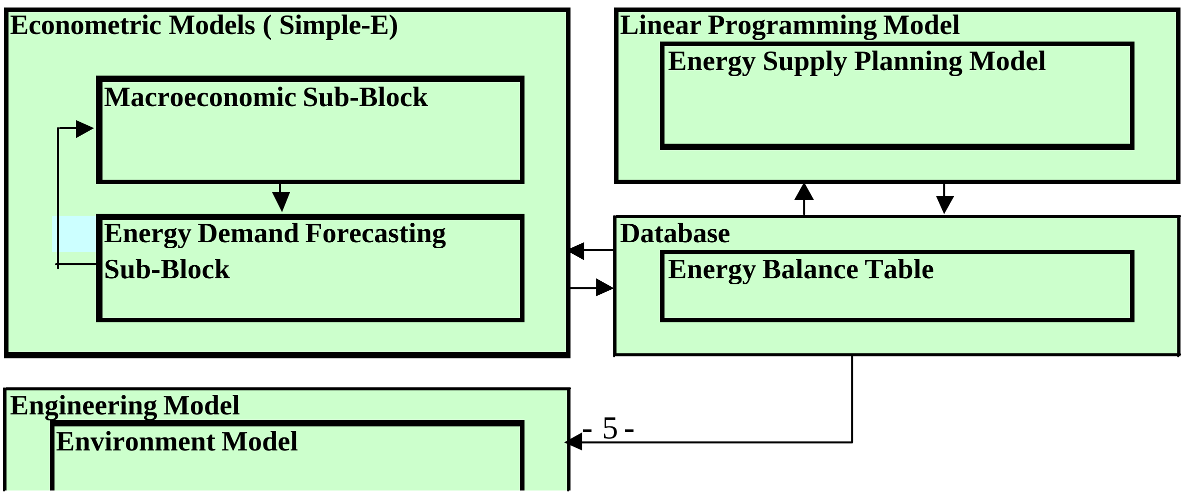
1.4 Configuration of Models

Figure 1.3.1 shows the configuration of a proposed energy economic model. Models are comprised of a series of the Macroeconomic energy demand forecasting model, the Energy supply planning model, the Environmental impact analysis model and the Database. And models are categorized into the models to be developed by econometric tool (Macroeconomic model and Energy supply/demand model) and a model (Energy supply planning model) by linear programming tool.

Each model was developed separately. The Macroeconomic model and the Energy demand forecasting model were linked as one model system, which covers from final energy consumption to primary energy requirement. The Energy supply planning model is an optimization model to evaluate maximum benefit of the total energy supply system. As the Energy supply planning model involves objective function and constraints, the model is another model system to the Macroeconomic energy demand forecasting model. The Environment impact analysis model can link both of the Macroeconomic energy demand and the Energy supply planning model through the Database as an interface.

The Macroeconomic energy demand forecasting model can simulate macroeconomic activities and energy demand by scenario. The Energy supply planning model receives the forecasted energy demand and can simulate the best mix of energy to be the maximum benefit under the constraints of facilities' capacity. Both models can be used separately or simultaneously through the Database.

Figure 1.3.1 Block Diagram of Model Configuration



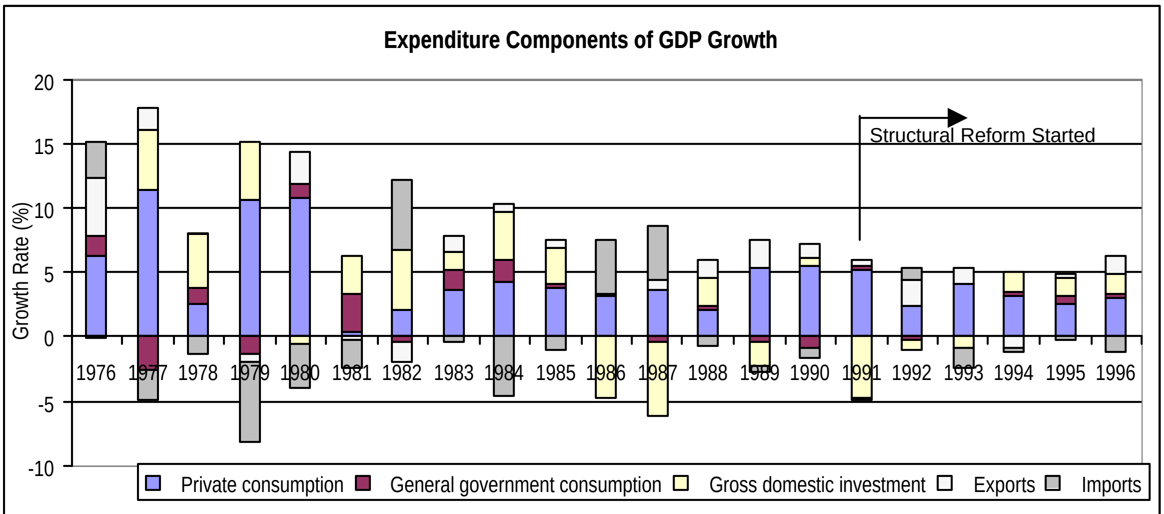
2. Economy and Energy Demand in Transition

2.1 Economy in Transition

Egypt is said to be the economy in transition. Here presented is the summary of the characteristics.

Figure 2.1.1 shows the contribution ratios of GDP growth from the point of expenditure. The period of high crude oil prices, between the mid 70s and the early 80s, could be characterized by the strong consumption and the strong investment. The imports and the government consumption were the major source of fluctuation. In the mid 80s, the international crud oil prices crashed. Since then, the decrease in investment and the weak government consumption were the characteristics until 1993.

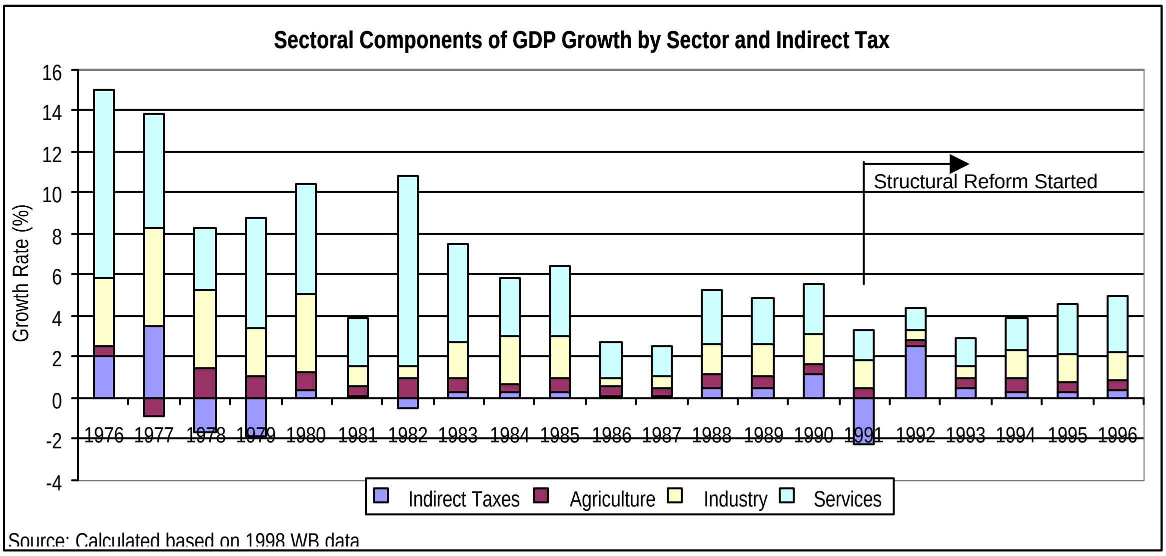
Figure 2.1.1 Expenditure Components of GDP Growth



Source: Calculated based on 1998 WB data

Figure 2.1.2 shows the sectoral contribution ratios of GDP growth. Through the whole period in the graph, the contribution of the service sector and the industrial sector is eminent compared to that of the agricultural sector. However, the contribution of the service sector and the industrial sector began to shrink in the early 80s and reached the bottom in 1987 just after the crash of the crude oil prices. The negative growth of indirect tax in the 1991 and the recovery in 1992 could be attributed to the introduction of sales tax to reduce the government budget deficit. The stable growth, although not strong compared to the past, seems to come back since 1993.

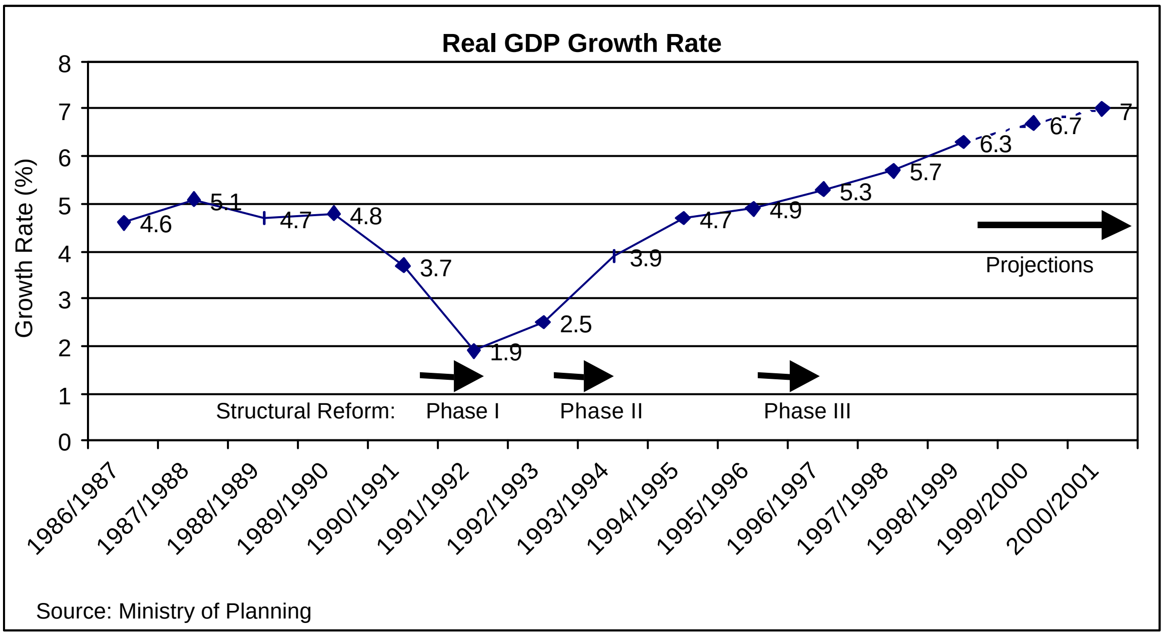
Figure 2.1.2 Sectoral Components of GDP Growth



As such, Egypt seems to have entered a phase of steady growth since 1993. This recent improvements are said to be attributed to ERSAP. In fact, the growth seems to match the phases of ERSAP (See Figure 2.1.3).

The phase I of the structural reform started in 1991. First, Egypt lifted most foreign exchange controls, unified the exchange rate, instituted a sales tax, reduced the budget deficit, freed interest rates and began financing the deficit through Treasury bill auctions. Since then, a stable Egyptian pound (LE) exchange rate against the dollar and high interest rates have prompted dedollarization and fed a steady growth in the money supply. At the same time Egypt imposed a strict fiscal and monetary policies. As a result, Egypt has reduced inflation to approximately 7% by 1997 from 25% in 1990. The budget deficit was reduced to 1% of GDP in 1997/98, down from 17% in 1990/1991. Furthermore, price controls on industrial products have been liberalized, except for goods such as pharmaceuticals, rationed sugar and edible oil. Now the level of energy prices reached to about 88% of international level.

Figure 2.1.3 Real GDP Growth Rate and the Projections



The phase II of structural reform began in 1993 focusing on privatization based on the IMF Extended Fund Facility Agreement. Then, in early 1996, following the creation of a new Cabinet, Egypt entered a critical new phase of economic reform (phase III). The focus is on improving Egypt's export competitiveness, liberalizing its trading regime by encouraging the private sector, eliminating obstacles to doing business in Egypt and improving Egypt's investment climate.

The future plan is ambitious. For example, Egypt is planning to redouble GNP once each ten years, to reach in 2017 more than fourfold its present level. To realize this kind of ambitions goal, an annual average investment of at least LE 100 billion is required over the coming 20 years. At least 25% of GNP will be required to meet such volume of investments.

2.2 Turning Point of Energy Supply/Demand

Figure 2.2.1 shows historical trends of Egyptian economy and energy. In the figure, polygonal line means annual growth rate (%) of GDP and bar graphs mean primary energy requirement (PER, million toe) and electricity generation (Elec. Gene., TWh). As for the GDP trend, we can find two turning points, the first of which occurred in1986/87 and the second in 1991/92, when Egypt promulgated ERSAP (Economic Reform and Structural Adjustment Program).

Figure 2.2.1 Historical Trend of Economy and Energy

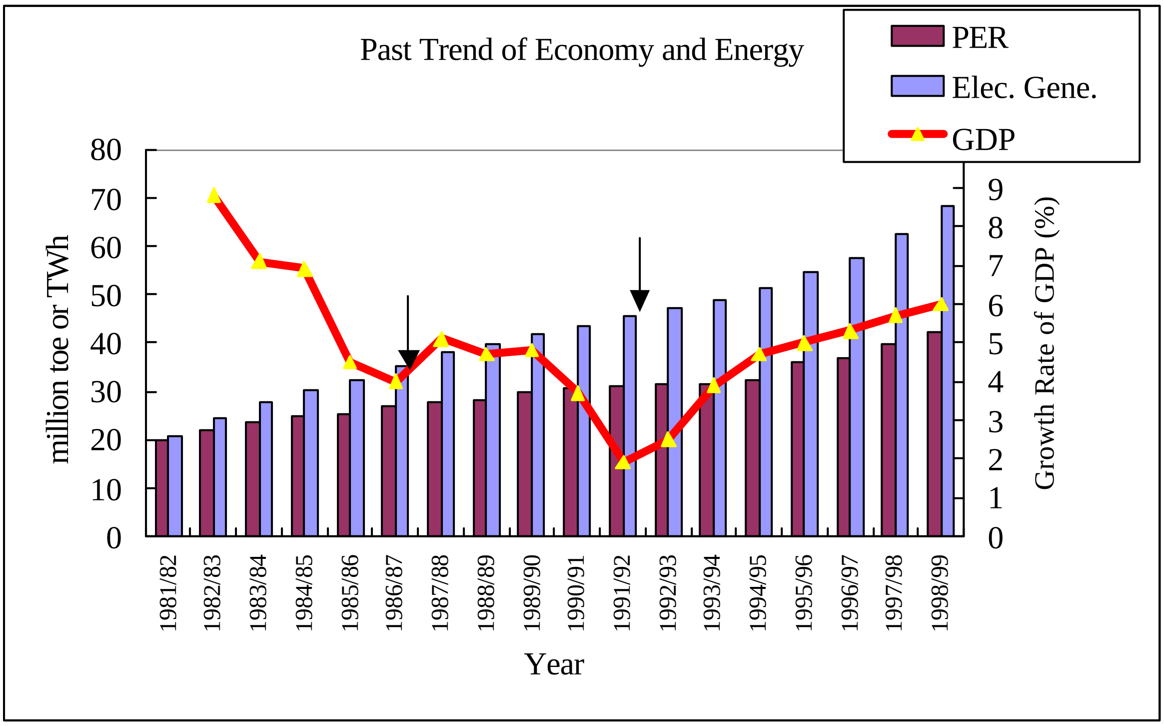


Figure 2.2.2 shows annual growth rates (%) of primary energy requirement (PER), electric power generation (Elec. Gene.) and consumption (Elec. Cons.). The turning points corresponding to GDP growth's change, seems to be trail GDP trend by about two years. The points, in 1988/89 and 1993/94, are sometimes used as the beginning year of observation period for regression analysis of model building.

Table 2.2.1 shows average annual growth rates of GDP and energy supply/demand for the periods of 1981/82-1986/87, 1986/87-1991/92 and 1991/92–1998/99. Elasticity with respect to GDP is also shown in the Table. In general, the 1981/82-1986/87 period indicates the structure of over-consumption of energy, and the next 1986/87-1991/92 period was the adjustment period for energy conservation or energy efficiency. And from 1991/92, energy supply and demand structure moves toward reconstruction, especially in the electricity sector.

Figure 2.2.2 Annual Growth Rate of Primary Energy Requirement and Electricity

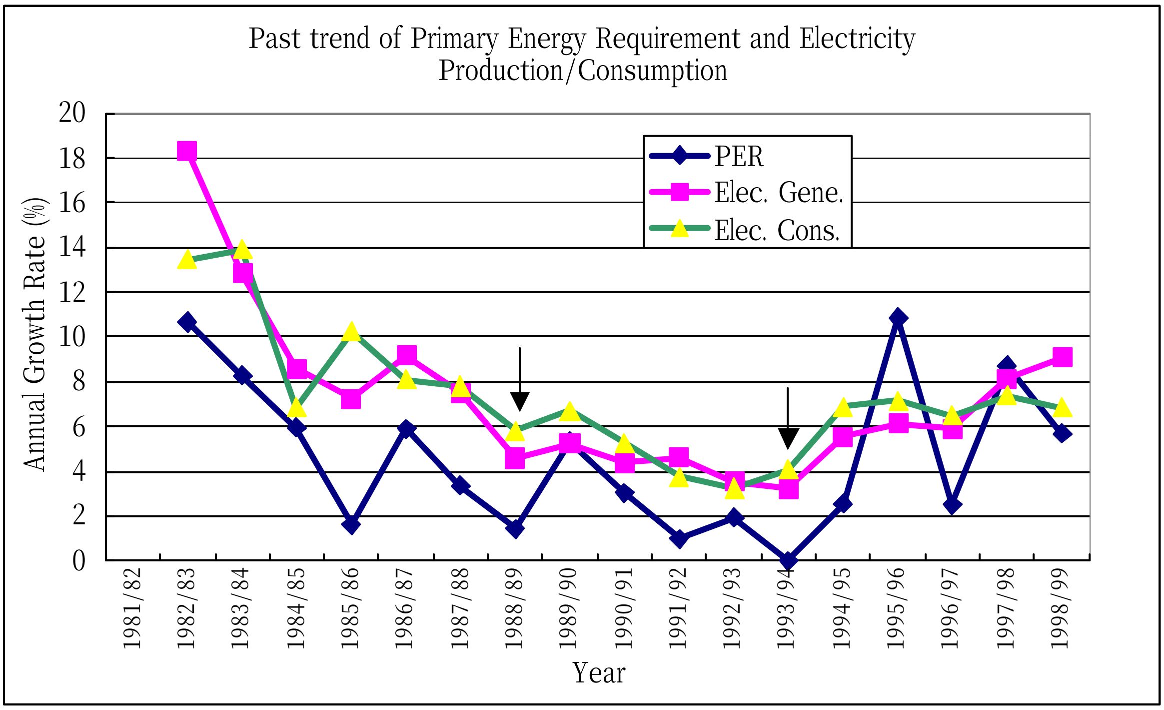


Table 2.2.1 GDP Growth Rate and Elasticity to GDP

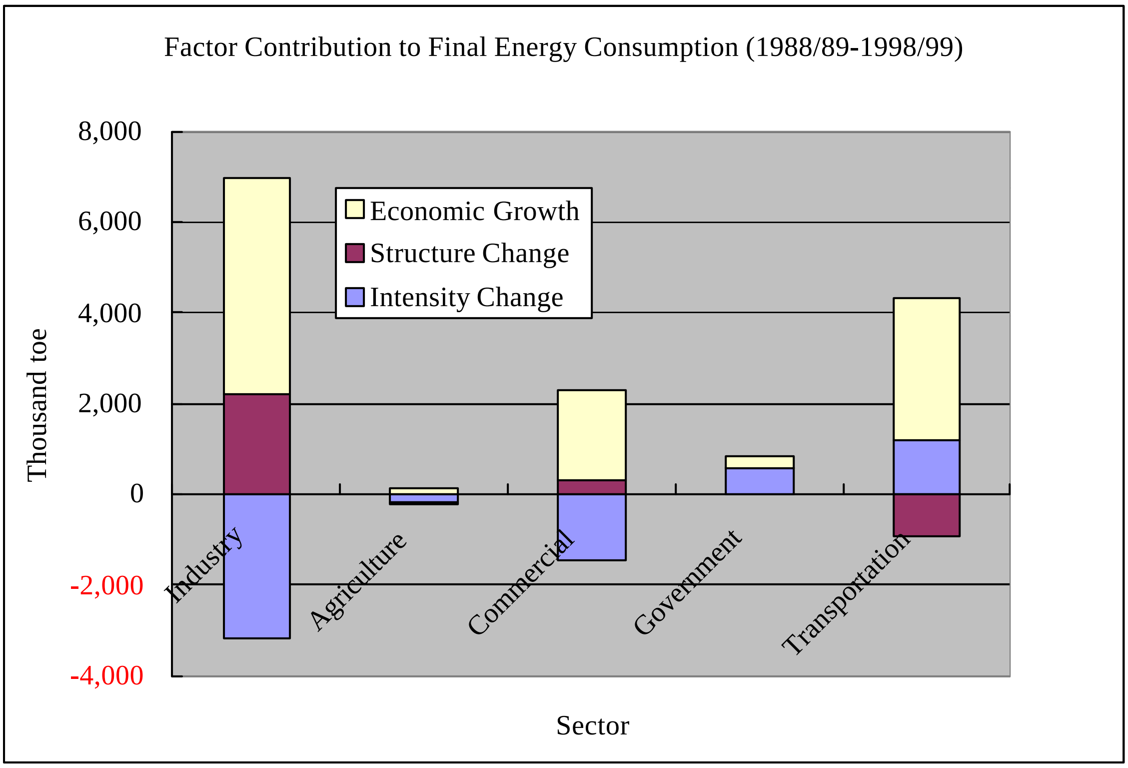
	1981/82-86/87	1986/87-91/92	1991/91-98/99
Growth rate (%)			
GDP	6.24	4.03	4.72
Primary Energy Requirement (PER)	6.43	2.81	4.54
Final Energy Consumption (FEC)	7.21	2.30	4.63
Electricity Generation	11.15	5.26	5.91
Electricity Consumption	10.46	5.86	5.99
Elasticity to GDP			
Primary Energy Requirement (PER)	1.03	0.70	0.96
Final Energy Consumption (FEC)	1.15	0.57	0.98
Electricity Generation	1.79	1.30	1.25
Electricity Consumption	1.68	1.45	1.27

(1) Factors behind the Increase of Energy Demand

The study team attempted to analyze the increase of primary energy requirement with three factors: 1) energy intensity per GDP, 2) GDP per capita, and 3) population. The energy intensity per GDP represents the energy volume required to produce a certain amount of added value. GDP per capita represents the economic level (not economic size). Figure 2.2.9 also shows the factors' contribution to primary energy requirement during each observation period; 1981/81-1988/1989, 1988/89-1993/94 and 1993/4-1998/99. The analysis showed an intensity improvement in the last period (latest five year). On the other hand, in the electric power sector, the intensity has improved in each period.

Next, examined were the factors that caused changes in energy consumption. The study team dis-aggregated this into three factors: 1) change in energy intensity in each industry (agriculture, manufacturing, transport, commercial, etc.), 2) change in industrial structure, and 3) change in economic activities. Basically energy demand increase is dependent on economic growth rate, however, the structural change has boosted energy consumption recently. This implies industrial activities are shifting to the energy consuming industry. Looking into by sector, the intensity change for improvement is identified in the industrial and the commercial sectors. In the transportation sector, on the other hand, the structure change reduced energy consumption, and the intensity change boosted the energy demand.

Figure 2.2.3 Factor's Contribution to Final Energy Consumption in each Sector



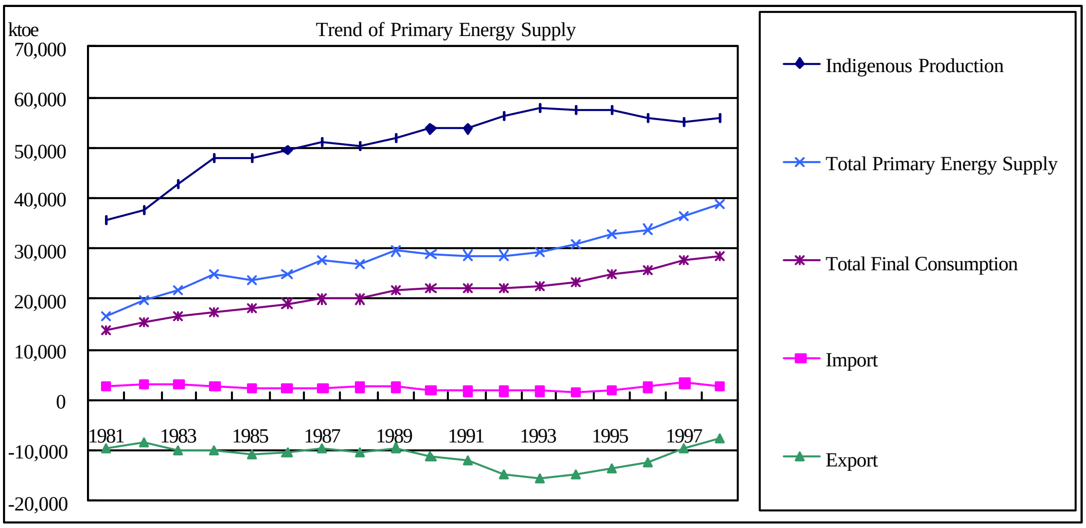
3. Outline of Energy Supply and Demand

3.1 Primary Energy Flow

Reserved crude oil and natural gas in Egypt are 3.5billion bbl and 31.5 tcf (BP-Amoco Report 1999), respectively. Domestic energy consumption has been covered by these natural resources. Primary energy has been produced mainly in Suez Gulf area. The recent significant discovery is the natural gas and condensates in Nile Delta and Western Desert.

Figure 3.1.1 shows the trend of energy flow from indigenous production to total final consumption. This trend shows that indigenous production has been declining in recent years, but domestic energy consumption has been increasing year by year. Therefore, exportation of primary energy, crude oil, has rapidly come down in the last 4 years. Coking coal is imported, and small amount of petroleum products are imported. Domestic supply of primary energy is currently 69% of primary energy production, 52% of which is transferred to final consumption via the conversion sector.

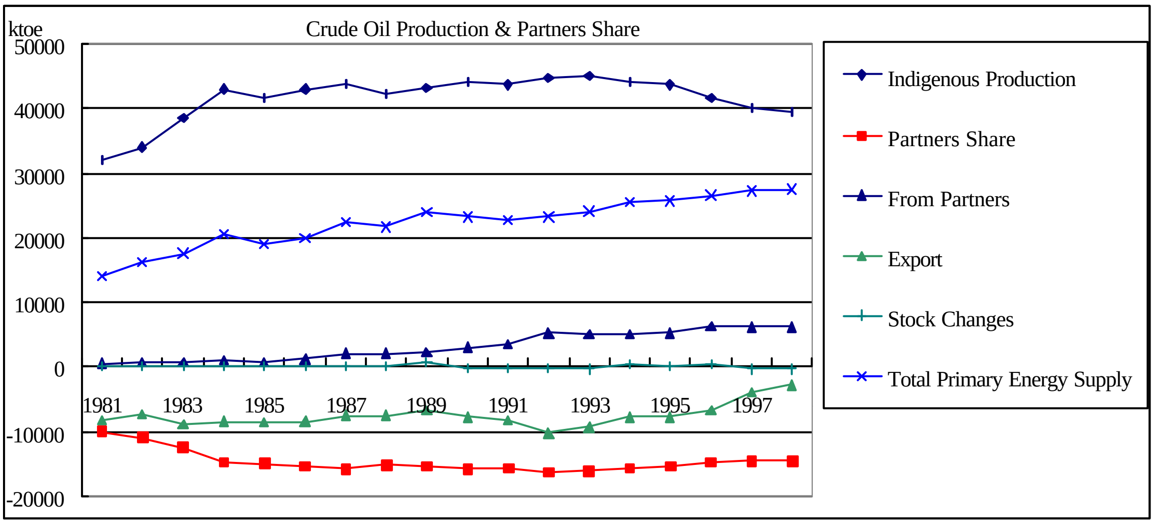
Figure 3.1.1 Primary Energy Supply



Source: Prepared from OEP Annual Report "Energy in Egypt"

Primary energy production in Egypt has been mostly depending on foreign investments and technologies, dubbed "Partners". There are some contracts to develop and operate oil and gas fields between Egypt and "Partners." "Partners" can have some amounts of field products according to the contract. Egypt has to pay for the net expenses by crude oil and etc. to "Partners" who is operating oil and gas fields. After that, Egypt buys some amounts of crude oil and natural gas from "Partners" at the market price, FOB. In other words, Egypt can get all of the natural resources except for crude oil, whereas "Partners" will get some amounts of crude oil in their hands. This is the framework of the current flow of natural resources in Egypt.

Figure3.1.2 Crude Oil Production and Partner Share



Source: Prepared from OEP Annual Report "Energy in Egypt"

As for crude oil, the production trend is shown in Figure 3.1.2. The shares of "Partners" have been stable, even though the crude oil production has declined year by year. As a result, exportation of crude oil by Egypt had to be rapidly declined in the last several years to satisfy the growing domestic demand of petroleum products in Egypt.

3.2 Energy Supply

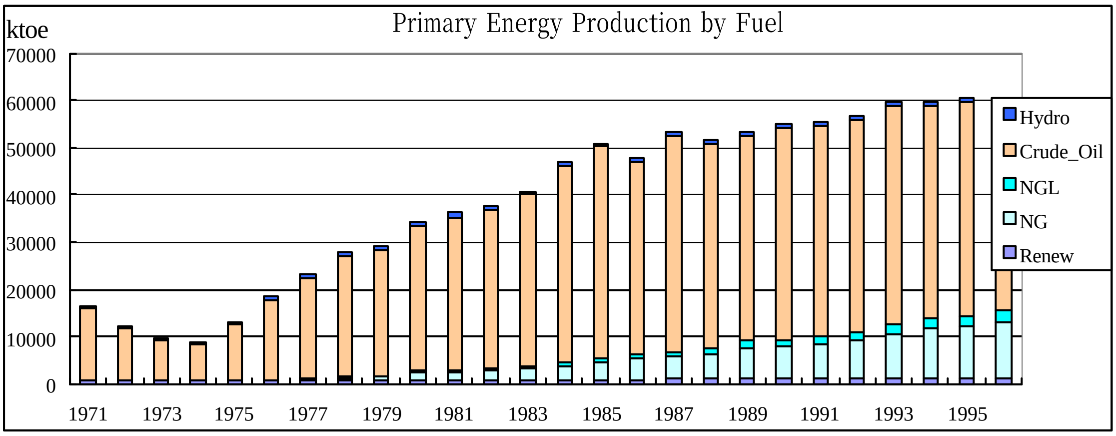
3.2.1 Primary Energy Production

Figure 3.2.1 shows the trend of primary energy production in Egypt. Crude oil has been the traditional primary energy production in Egypt. But the production amount, which has been mainly contributed by Suez Gulf region, is gradually slowing down in recent years instead of investigating and developing to recover the crude production. The Western Desert, however, continues to make significant discoveries in the area, slowing the declining crude production in Egypt.

On the other hand, natural gas production has been increasing rapidly at the newly discovered gas fields. In this context, domestic natural gas consumption is growing while the domestic use of petroleum products is declining. Nile Delta and the offshore areas along the Mediterranean Coast is one of the world scale natural gas reservation. Actually, several big investments for discovering natural gas are now undergoing in the areas.

Big discovery of new gas field is continuing in Nile Delta and offshore areas, and some drilling has brought the largest yield in gas production. Commercial operation in those new gas fields to supply natural gas is expected in early 2000. Under this new situation, the Government of Egypt has a plan to transfer domestic energy supply from petroleum products to natural gas. It also has some strategic plan to build several gas transportation lines for natural gas export to neighboring countries, and recently Egypt have reached the protocol agreement with Turkey to begin supplying LNG from Egypt by2004.

Figure 3.2.1 Primary Energy Production by Fuel



Source: IEA, "Energy Balance and Statistics of Non-OECD Countries, 1997

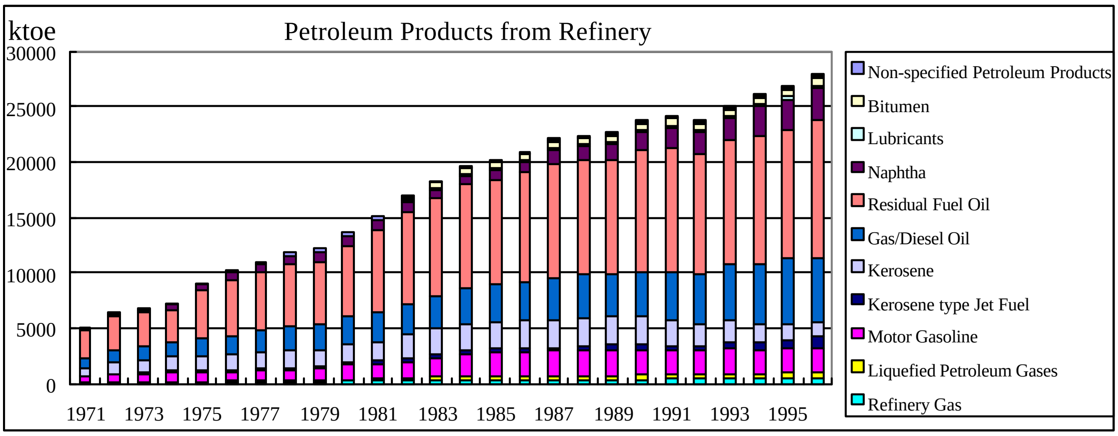
The coal, of which a small amount is indigenously produced of coal in Sinai Peninsula, is entirely exported to international markets. By contrast, Egypt imports Coking Coal to convert in Coke Oven.

3.2.2 Refinery Sector

All crude is refined in EGPC refineries, mainly for domestic supply. Some of fuel oil and base oil for lubricants are exported. Importation of petroleum products is currently very small.

The total capacity of refineries in Egypt is 578,000bbl/d in 1998 as crude throughput. Figure 3.2.2 shows the trend of Petroleum Products from all refineries in Egypt. The increasing trend of the share of light petroleum products, which have much more value added in the market, is found. Especially, the diesel oil production is increasing to meet the domestic demand, while gasoline is stable and fuel oil is decreasing.

Figure 3.2.2 Petroleum Products from Refinery



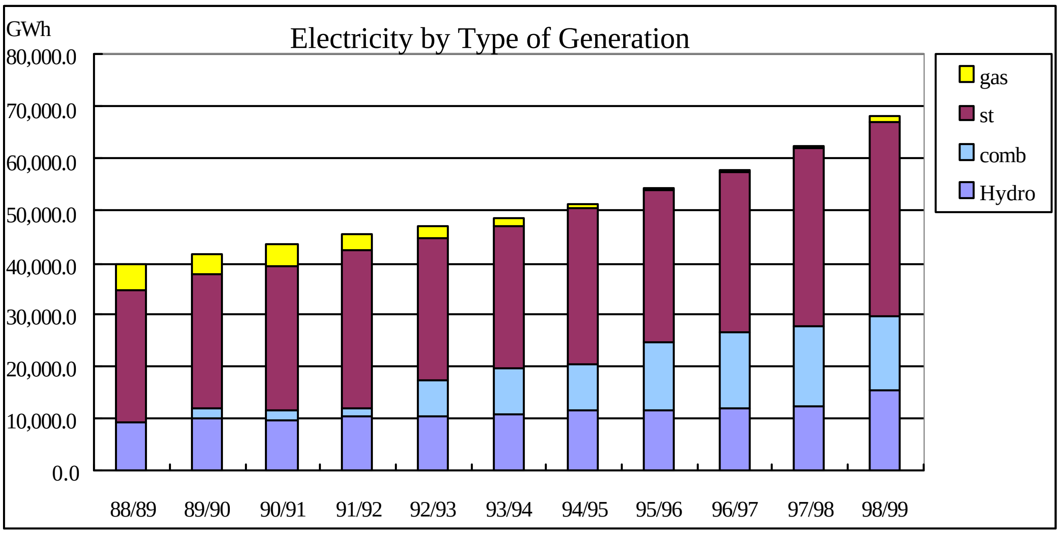
Source: IEA, "Energy Balance and Statistics of Non-OECD Countries, 1997

3.2.3 Electricity Sector

Current installed total capacity of power generation in Egypt is 13,935MW; thermal 11,125MW, hydro 2,810MW, according to EEA (Egyptian Electrical Authority) report, 1998/99.

Maximum generation in 1998 was 10,919MW, excluding independence generation. Annual load factor was comparatively high at 71.1%.

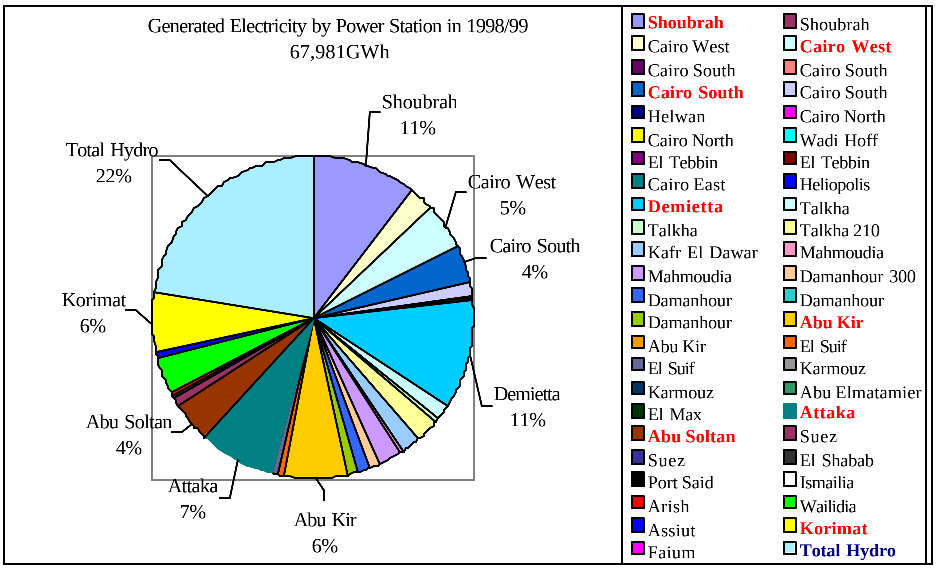
Figure 3.2.3 Electricity Generation by Type



Source: Prepared from EEA Annual Report

(Note) "gas" is gas turbine, "st" is thermal power, "comb" is combined cycle and "Hydro" is hydro power

Figure 3.2.4 Generated Electricity by Thermal Power Station



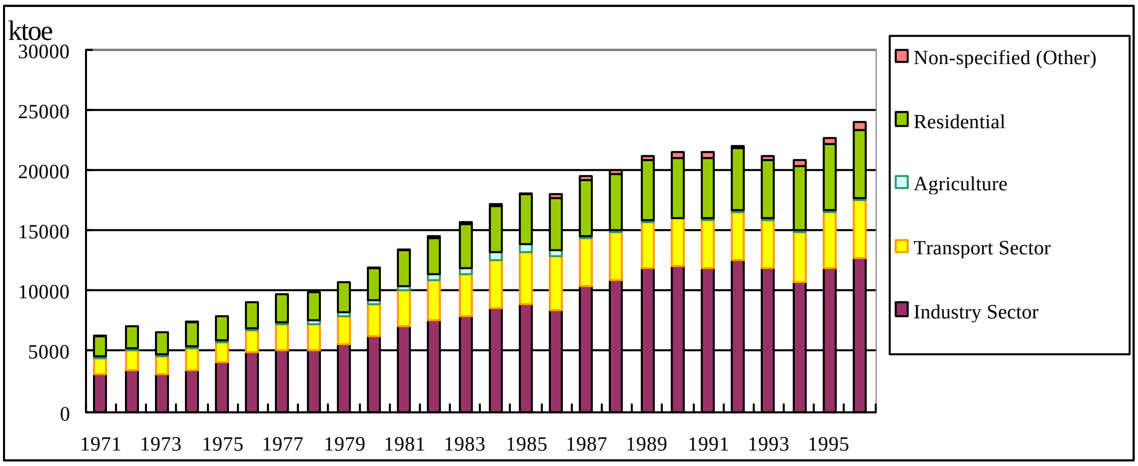
Source: Prepared from EEA Annual Report

Figure 3.2.4 shows the generated electricity from all thermal power stations in Egypt. Main power stations are Damietta in Nile Delta, Shoubrah and Cairo West in Cairo, Abu Kir in Alexandria and, Attaka and Abu Soltan in Suez. 60% of thermal power generation and 50% of total electricity is generated by these 6 main power stations. The newest Kureimat (1,200MW) in the far south of Cairo has begun to send its generated power to grid.

3.3 Final Energy Demand

A brief look at the past trend of energy consumption in Egypt shows that the growth of energy consumption slowed down slightly declined in the early 1990's. After that it has been growing again till now. Figure 3.3.1 shows the trend of energy consumption by sector. The most energy intensive sector is the industrial sector, followed by the transportation sector and the residential sector. The annual energy growth rate in the transportation sector is especially remarkable.

Figure3.3.1 Final Energy Consumption by Sector



Source: IEA, "Energy Balance and Statistics of Non-OECD Countries, 1997

4. Tools for Energy-economic Model Building

4.1 Econometric Simulation System

4.1.1 Macroeconomic Model: Basic Principles

A macro econometric model consists of equations, which represent the relationships between the variables in the system of national accounts and other key statistics. The parameters of the equations are empirically estimated based on time series and cross section data.

The macroeconomic model must be based on the macroeconomic principles, although the actual applications of the principle differ by the type of the economy. The primary parts of the models are (1) consumption, (2) investment, (3) export/import, and (4) wages and deflators.

4.1.2 Econometric Methods

Econometric methods rely upon hypothesis testing of behavioral relationships as posited by economic theory as mentioned above, using statistical methods.

The econometric model contains an endogenous variable and a set of exogenous explanatory variables. Information on the dependent variable and the explanatory variables represents the observation set, and the parameters of the relationship are unknowns. The theory is based on the inclusion of a stochastic error term or the regression models, which differentiate this method from the deterministic technique like linear programming.

The most popular regression model is to use the estimator called ordinary least square (OLS). OLS provides estimates of parameters by minimizing the sum of squares of the difference between the observed value of the endogenous variable and the linear relationship specified on the independent variables.

The exact mathematical form of the relationship is usually not defined by economic theory; assumptions of linearity are norm. Therefore, the objective is to find the most appropriate functional form for the relationships. The modeling process involves the estimation of alternative relationships and then the reporting of the single equation that the analyst considers most appropriate.

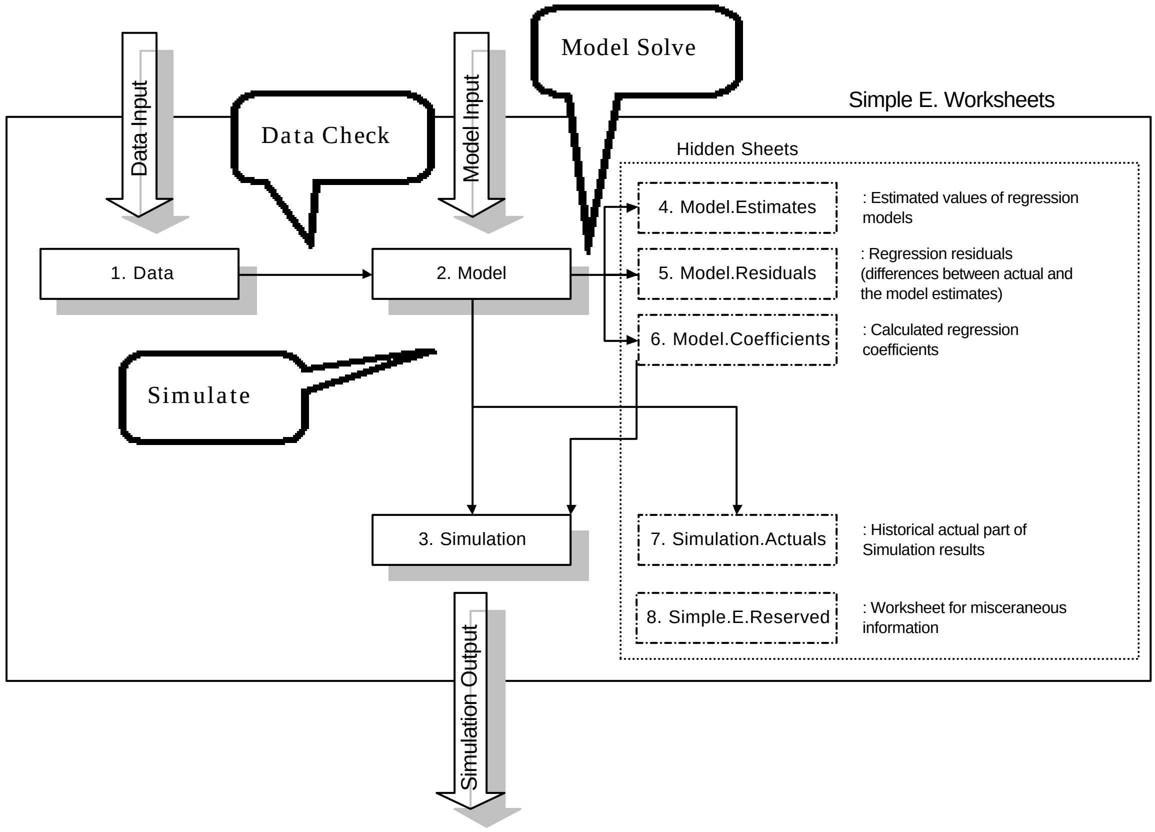
4.1.3 Econometric Simulation Tool: *Simple E.*

The principal tool for the econometric simulation will be Simple E (Simple Econometric Simulation System by The Institute of Energy Economics, Japan). *Simple E.* is an Excel Add-In software and it works with an *Excel* workbook file that includes three sheets—Data, Model, and Simulation.

Simple E. cannot work without these sheets, whereas inputs and outputs in these three sheets can be used independently without *Simple E.* Each flow is processed in these specially designed worksheets. The next diagram shows the basic concepts and the relationship of these processes with the worksheets of Simple E.

Figure 4.1.1 Conceptual Diagram:

Conceptual Diagram of Simple E. Worksheets



As shown in the above diagram, first, users have to prepare the necessary data and their idea of model specifications. Next, the users have to prepare the data in "Data" sheet and the model specifications in "Model" sheet. The rest of the tasks from model checking to simulation are the works of *Simple E.*

4.2 Linear Programming

4.2.1 Objective of Linear Programming Model (LP model)

Linear programming method uses an objective function to maximize or minimize its target by finding feasible values of the related variables of the objective function. The values given to the variables are called optimal solution. An LP method will be applied to a supply planning model to obtain the optimum solution (maximum value or minimum value) in consideration with the following points.

1) In an energy supply planning model by an LP method, the variables should include such variables as energy production, import, sales volume, export, stock and so on.
2) In the model, constraints of the variables should include production capacity, import upper limit, demand, export upper limit, stock upper limit and so on.
3) In the model, the target of the objective function is generally the cost minimum or the profit maximum.

4.2.2 Structure of LP model

The following is the procedures to formulate and define an objective function, variables and constraints to building up as LP model.

(1) Objective Function

The target of an objective function is the cost minimum or the profit maximum. The selection of the target depends on the objective of the model and the data availability. As is frequently the case, the supply planning model and the production planning model are built up in order to increase effectiveness of the organization concerned (Ex. Private company or Government organization). Therefore, the objective function is usually formulated to maximize the profit. However, if the organization such as that of infrastructure businesses does not have a clear benefit measurement, the target of the objective function is defined by the cost minimum. It is sometimes called " resource allocation model".

(2) Variables

Variables defined in LP method are unknown elements, which are determined internally. The values in the variables gradually converge from initial value 0 to optimal solutions in an LP model. Therefore, when an LP model is built up on MS-Excel sheet, variable cells do not accept any value or formula externally. If they are set externally, they will be reset with 0 when the model is started. Which items are set as variables in an LP model? It depends on the model builder's design. Generally, all items in an LP model can be set as variables.

(3) Constraints

Constraints in an LP model can be classified into three categories. Generally, constraints in an LP model are formulated in line with the actual physical structure. Therefore, when constraints are put in an LP model, the constraints are defined in the real production as well as in the real trading. In some cases of many constraints in an LP model, the model could halt computation because it cannot reach a feasible solution within the constraints.

There are many software packages to build up and to solve an LP model. In this project an Excel Add-in LP package called "Large Scale LP Solver" is adopted.

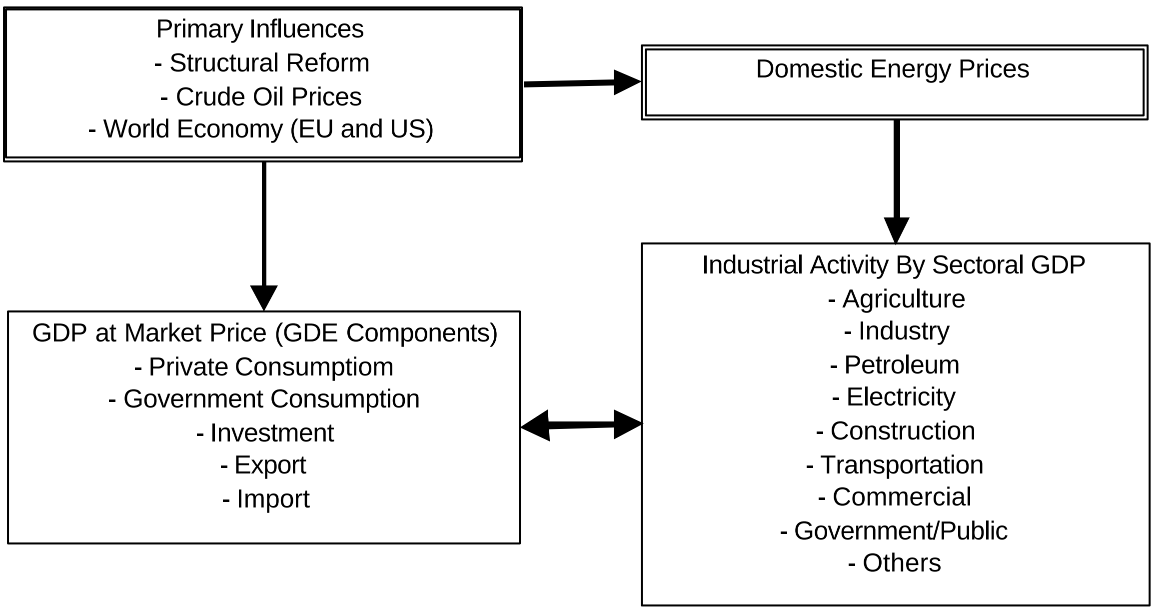
5 Macro-econometric/Energy Demand Forecasting Model

5.1 Macro-econometric Block

The objective of macro-econometric model in this study is to address the relationships of ERSAP, international crude oil price, domestic energy price, and major industrial activities.

The basic idea is that the overall magnitude of GDP is a function of major external influences of structural reform, crude oil price and world economy. Because factors such as structural reform and world economy will influence overall economy from various aspects, they do not distinguish one specific sector, except for the case of crude oil, which has a direct link with the petroleum sector. On the other hand, the sectoral value added was used to represent the industrial structure in relation to such domestic parameters as energy prices. Especially the influence of energy price as one of the components energy cost was emphasized.

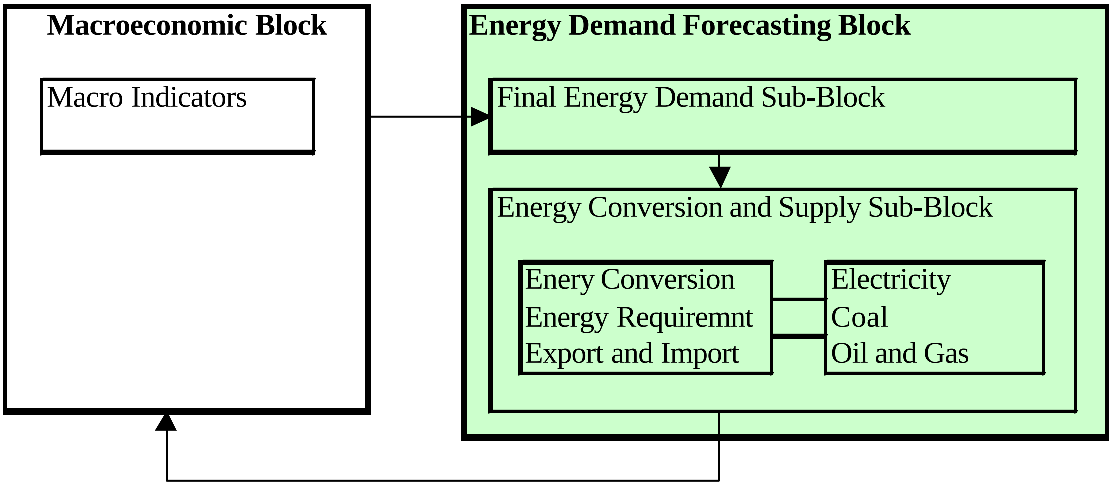
Figure 5.1.1 Basic Concept



5.2 Energy Demand Forecasting Block

An energy demand-forecasting model block consists of a final energy demand sub-block, and an energy conversion and supply (energy requirement) sub-block as shown in Figure 5.2.1. The model computes end-use energy demand in each of the final energy demand sectors, using economic indices obtained from the macro-economic model block. Taking into account of fuel inputs and conversion losses in the conversion sector such as electric power generation and oil refining, the primary energy requirement is estimated. The model can handle the energy flow from the final energy demand to the energy supply basing on the energy balance table can introduce the development plan such as crude oil, natural gas and electric power source.

Figure 5.2.1 Schematic Diagram of Energy Demand Forecasting Model



5.3 Simulation Results

In this section, simulation results by macroeconomic-energy demand forecasting model are described. Base year and target year of the model are F.Y. 1998/99 and F.Y. 2005/06 respectively. Although there are many scenarios to be considered, the following three kinds of energy price scenarios are set in this section.

1) Nominal price constant (low price scenario)
2) Real price constant (base price scenario)
3) Real price increase 10 % annually (high price scenario)

5.3.1 Summary of Simulation Results by Price Scenario

Table 5.3.1 shows the summary of results by price scenario described above. The annual growth rates (G.R) of primary energy requirement was 5.44%, 5.64% and 6.01% in each case of high price case, real price constant case and low price case, respectively. The GDP growth rates during the simulation term (1998/99-20005/06) are 5.77%, 5.74% and 5.68%, respectively. As the results, the elasticity of primary energy requirement with respect to GDP was 0.94, 0.98 and 1.06, respectively. As for the final energy demand, the growth rates in each scenario were 5.04%, 5.27% and 5.71%, and their elasticity was 0.87, 0.92 and 1.01 respectively. In every case, natural gas demand will reach the highest growth rate of over eight percent. The demand of other energy sources such as crude oil and petroleum products will remain around four percent growth.

Table 5.3.1 Summary of Main Results by Scenario

		High Price Case		Real Price Constant		Low Price Case	
	1998/99 (ktoe)	G.R (%)	2005/06 (ktoe)	G.R (%)	2005/06 (ktoe)	G.R (%)	2005/06 (ktoe)
Energy Requirement Total	44,064	5.44	63,845	5.64	64,675	6.01	66,291
Primary Energy							
Coking Coal	1,360	2.04	1,567	2.44	1,610	2.96	1,669
Natural Gas	12,799	8.38	22,476	8.47	22,610	8.64	22,862
Crude Oil	27,400	3.79	35,547	4.10	36,294	4.70	37,800
NGL	1,671	3.79	2,168	4.10	2,213	4.70	2,305
Secondary Energy							
Petroleum Products	24,057	3.63	30,877	3.91	31,467	4.46	32,652
Electricity (Generation)	5,848	6.23	8,925	6.33	8,989	6.53	9,107
Final Energy Demand							
Agriculture	320	3.77	414	4.39	432	5.34	460
Industry	10,775	5.96	16,163	6.06	16,265	6.21	16,428
Transportation	9,113	4.08	12,058	4.49	12,394	5.37	13,145
Residential/Commercial	5,652	4.87	7,884	5.16	8,041	5.66	8,308
Government/Others	714	7.96	1,220	7.97	1,221	7.97	1,221
Non-Energy Use	1,923	3.66	2,474	3.66	2,474	3.66	2,474
Electricity (Demand)	4,868	6.48	7,555	6.59	7,609	6.79	7,710
Total	28,498	5.04	40,213	5.27	40,827	5.71	42,037
Elasticity to GDP							
Final Energy Demand		0.87		0.92		1.01	
Energy Requirement		0.94		0.98		1.06	
Electricity Demand		1.12		1.15		1.20	
Electricity Requirement		1.08		1.10		1.15	
Gross Domestic Product	268,341	5.77	397,500	5.74	396,544	5.68	395,071

Regarding the demand for petroleum products, the total growth rates were 3.6%, 3.9% and 4.5% in each price scenario. The forecasted results of main petroleum products are shown in Table 5.3.2. LPG is forecast to be the record growth rates of 6.8%, 7.3% and 8.2% in each scenario, followed by diesel oil (gas oil) of around 5.8% growth rate. Gasoline demand will fluctuate from 3.3% to 7.6% growth rates with the price scenario. From the results of this simulation, gasoline is the most sensitive to price. Kerosene demand is forecast to decrease rapidly around –10% as shown in Table 5.3.2.

Taking fuel switch policy from petroleum products to natural gas into consideration, its main target will be LPG and diesel oil from the view point of demand size, and LPG and gasoline from the view point of price policy. Fuel oil will be able to complement the short-term shortage of natural gas supply capacity.

Table 5.3.2 Forecasted Results of Main Petroleum Products

Petroleum Products		High Price Case		Real Price Constant		Low Price Case	
	1998/99 (ktoe)	G.R (%)	2005/06 (ktoe)	G.R (%)	2005/06 (ktoe)	G.R (%)	2005/06 (ktoe)
LPG	2,376	6.76	3,756	7.32	3,895	8.19	4,123
Gasoline	2,432	3.26	3,045	4.71	3,356	7.59	4,060
Jet Fuel	454	2.00	522	2.13	526	2.38	535
Kerosene	1,166	-11.04	514	-10.27	546	-9.11	598
Diesel	7,670	5.71	11,316	5.76	11,351	5.85	11,419
Fuel Oil	8,979	2.34	10,555	2.42	10,612	2.56	10,720
Lubricant	338	3.72	437	4.08	448	4.64	465
Bitumen	883	3.04	1,088	3.17	1,098	3.39	1,114
Petroleum Products Total	24,057	3.63	30,877	3.91	31,467	4.46	32,652

Table 5.3.3 Forecasted Results in Power Sector

Electricity Sector		High Price Case		Real Price Constant		Low Price Case	
	1998/99	G.R	2005/06	G.R	2005/06	G.R	2005/06
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)
Demand by Sector							
Agriculture	2,200	6.88	3,505	6.95	3,522	7.05	3,545
Industry	22,900	4.78	31,750	4.94	32,097	5.20	32,658
Residential	21,066	7.28	34,449	7.28	34,449	7.28	34,454
Commercial	2,134	9.23	3,959	10.20	4,213	12.25	4,792
Government/Others	8,300	7.96	14,190	7.97	14,201	7.97	14,202
Electricity Demand Total	5,604	6.48	8,698	6.59	8,760	6.79	8,876
Electricity Generation	68,000	6.23	103,776	6.33	104,518	6.53	105,900
Hydro-power	15,000	1.56	16,713	1.56	16,713	1.56	16,713
Thermal-power	53,000	7.35	87,063	7.48	87,804	7.72	89,187
Fuel Required							
Fuel Total	12,012	7.35	19,731	7.48	19,899	7.72	20,213
Petro. Products Total	4,337	4.16	5,770	4.29	5,819	4.52	5,910
Diesel Oil	129	-6.50	81	-6.50	81	-6.50	81
Fuel oil	4,208	4.40	5,689	4.53	5,738	4.77	5,830
Natural Gas	7,675	8.92	13,962	9.06	14,080	9.30	14,302

Forecasted results in the power sector are shown in Table 5.3.3. Electricity demand is forecast to be around six percent growth rates, 6.5%, 6.6% and 6.8% in each price scenario, and the elasticity with respect to GDP will be expected to be 1.12, 1.15 and 1.20, respectively. The highest growth rate is recorded in the commercial sector, followed by the government/public, residential, and agricultural sectors.

5.3.2 Simulation Results of Base Case

(1) Final Energy Demand Sector

In the final energy demand sector, industrial sector is the biggest energy consumer and the energy demand would increase at average growth rate of 6.1% per year from 10,775 ktoe in 1998/99 to 16,265 ktoe in 2005/06. Next energy consumer is transportation sector and the energy demand is likely to grow from 9,113 ktoe in 1998/99 to 12,394 ktoe in 2005/06 at average growth rate of 4.5%. Energy demand for residential/commercial sector grows at the pace of 5.2% growth and the demand is expected to be 8,041 ktoe in 2005/06 from 5,652 ktoe in 1998/99.

As for the final energy demand by energy source, the major source is petroleum products (See Figure 5.3.2). The share decreases from 68% in 1998/99 to 63% in 2005/06, maintaining the share above 60%. On the other hand, natural gas increases the share from 15% (1998/99) to 17% (2005/06), and electricity increases the share from 17% (1998/99) to 19% (2005/06). In the past, electricity accounted for 12% in 1985/86, 14% in 1990/91 and 16% in 1995/96.

Figure 5.3.1 Final Energy Demand by Sector

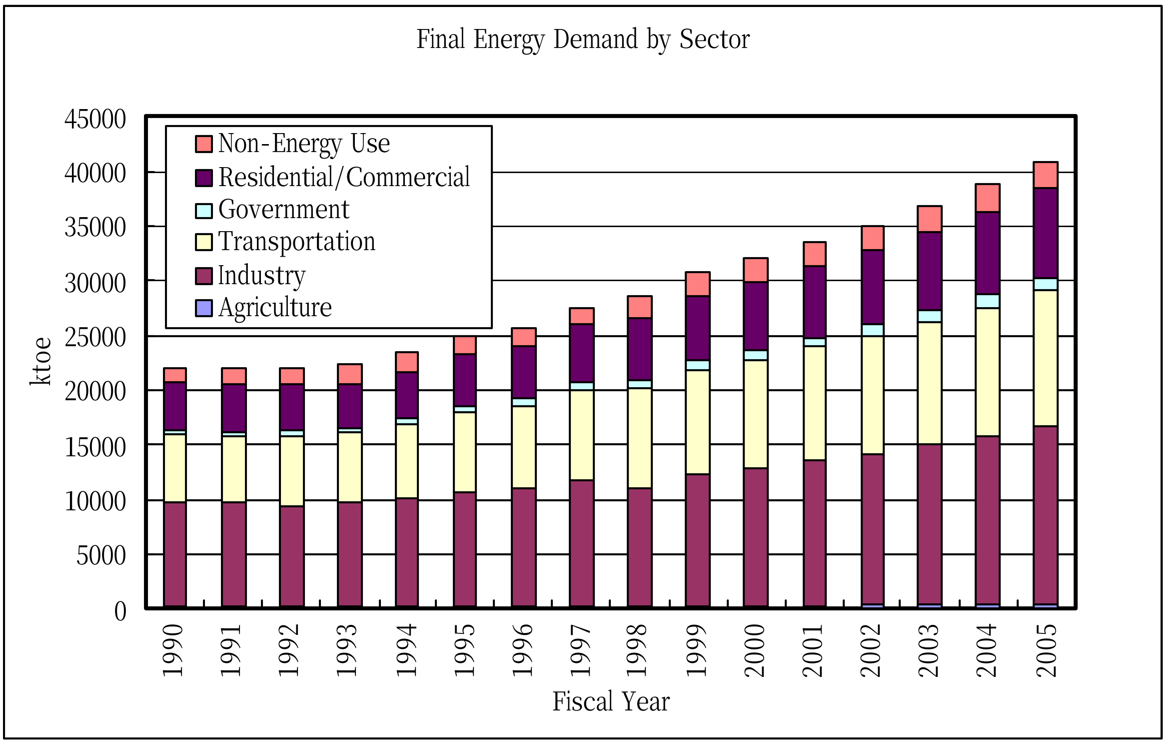
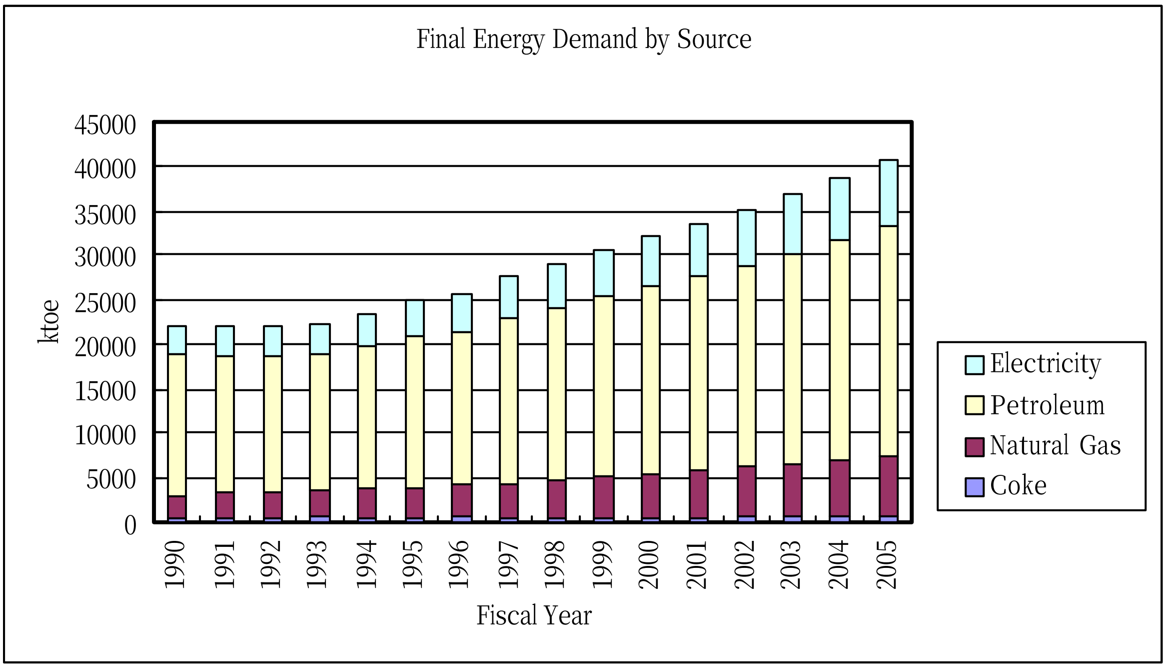
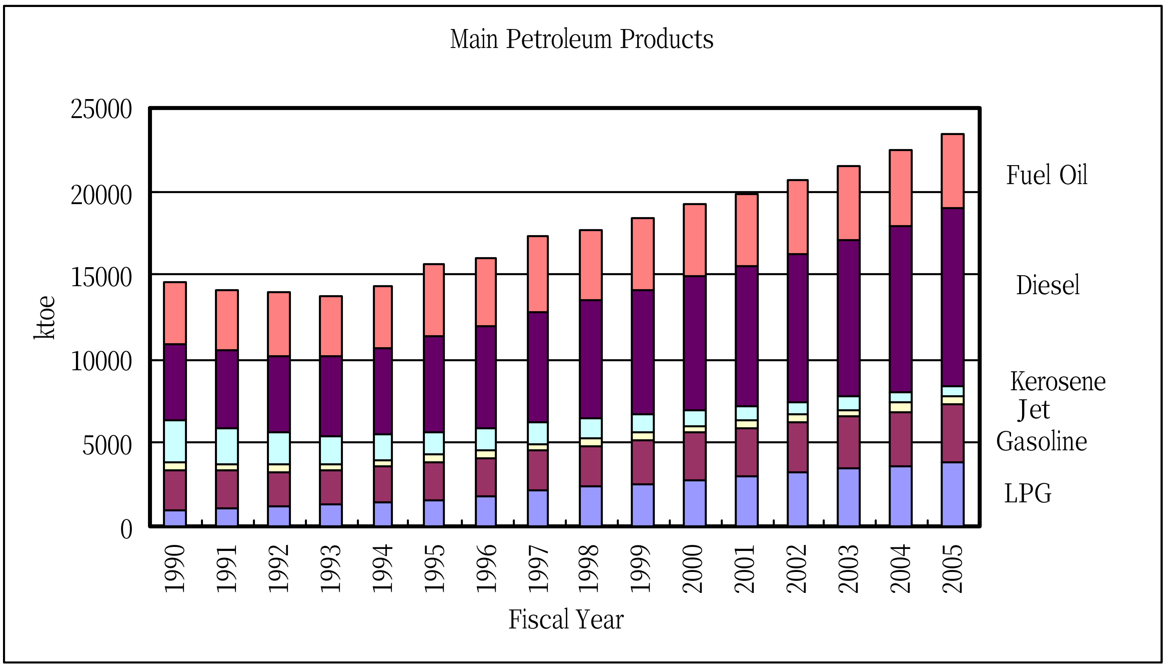


Figure 5.3.2 Final Energy Demand by Source



As seen in main petroleum products, diesel oil, LPG and gasoline demands have an increasing tendency (See Figure 5.3.3). Each share of diesel oil, LPG and gasoline will expand a little bit. The share of fuel oil will shrink. Diesel oil will keep a large share in petroleum products demand.

Figure 5.3.3 Main Petroleum Products Demand



1) Agricultural Sector

Energy demand for agriculture is forecasted to be from 320 ktoe in 1998/99 to 432 ktoe in 2005/06 at an average growth rate of 4.4%. The energy demand accounts for only one percent of the total demand. Other than electricity, kerosene and diesel oil are used as fuels in the agricultural sector. It is supposed that each energy carrier is used for irrigation (pumping).

Kerosene demand decreases rapidly, and electricity demand increases in place of fuels. This trend will continue beyond 2005/06. The share of electricity was just under 40% in 1990/91, and about 70% in 1998/99. It is likely to rise above 80% in 2005/06

2) Industrial Sector

Industrial sector is the biggest energy consumer. The energy demand will increase at an average growth rate of 6.1% per year from 10,775 ktoe in 1998/99 to 16,265 ktoe in 2005/06. As the result, the share of energy demand for the industrial sector increases from 38% in 1998/99 to 40% in 2005/06.

As for petroleum products, fuel oil had been playing a main role in the past. However, the role of fuel oil will get smaller relatively. On the other hand, diesel oil demand is projected to grow and expand the share. LPG demand also increases although it is small in quantity.

3) Transportation Sector

The transportation sector is a large energy consumer next to the industrial sector. Energy demand for transportation is likely to grow at an average growth rate of 4.5from 9,113 ktoe in 1998/99 to 12,394 ktoe in 2005/06. The share of the transportation sector in the total demand would remain slightly above 30%.

Diesel oil demand is climbing, followed by gasoline demand. The growth rates of main fuels for transportation, Gasoline, jet (aviation fuel), diesel oil and fuel oil, are shown in the following Table 5.3.4.

Table 5.3.4 Growth Rates of Fuels for Transportation

F.Y	1998	2005	G.R
	(ktoe)	(ktoe)	(%)
Gasolime	2,432	3,356	4.71
Jet	454	526	2.13
Diesel	5,242	7,337	4.92
Fuel Oil	717	810	1.75

4) Residential and Commercial Sector

The energy demand for residential/commercial sector grows at a pace of 5.2% growth rate, and the demand is expected to be 8,041 ktoe in 2005/06, up from 5,652 ktoe in 1998/99. The residential and commercial sector is the third largest energy consumer and has its own unique demand structure.

According to the simulation result, the demand for both LPG and electricity grows remarkably. Natural gas demand is also expected to rise. As a result, energy demand structure in the residential/commercial sector would clearly change. Kerosene, which took a large share in the past, loses the share. Electricity and LPG will take around 90% of the share. It is estimated that natural gas use will expand, based on the investment for gas supply infrastructure.

(2) Energy Conversion Sector

1) Oil refinery

The production of petroleum products is projected under an assumption that the total production of petroleum products will meet the total domestic demand of petroleum products. Table 5.3.5 shows the forecasted main petroleum products production. The total production of petroleum products is expected to increase at an annual average of 4.1% from 28,745 ktoe in 1998/99 to 38,075 ktoe in 2005/06.

Table 5.3.5 Production of Petroleum Products

	Actual			Forecasted			
Fiscal Year	1990	1995	1998	1999	2001	2003	2005
LPG	384	507	491	515	554	597	650
Gasoline	2,358	2,232	2,432	2,552	2,746	2,962	3,222
Jet	441	920	1,020	1,070	1,151	1,242	1,351
Kerosene	2,447	1,378	1,164	1,221	1,314	1,418	1,542
Diesel	4,402	6,193	6,456	6,773	7,289	7,864	8,552
Fuel Oil	11,372	12,205	12,415	13,025	14,016	15,122	16,445
Naphtha	1,800	2,980	3,284	3,445	3,707	3,999	4,349
Non-Specified	115	170	176	185	199	215	234
Lubricants	206	223	259	271	292	315	342
Bitumen	636	707	927	973	1,047	1,129	1,228
Petro. Coke	90	117	121	127	137	148	161
Non-Specified	115	170	176	185	199	215	234
Petroleum Products Total	24,252	27,632	28,745	30,157	32,452	35,012	38,075

2) Electricity sector

The electricity sector is a high growth sector and is expected to rise at a growth rate of 6.6%. Regarding the electricity demand by sector, demand for the industrial sector is likely to increase from 22,900 GWh in 1998/99 to 32,097 GWh (up 4.8% per year). Demand for the residential (household) sector is projected to climb from 21,006 GWh in 1998/99 to 34,449 GWh by 2005/06 (up 7.3% per year). The sector with the highest growth is the commercial sector, with the growth rate of 10.2%. The biggest consumer of electricity is the industrial sector, followed by the residential sector at the present. However, the demand for households will exceed the demand for industry by a remarkable growth in the residential and commercial sector.

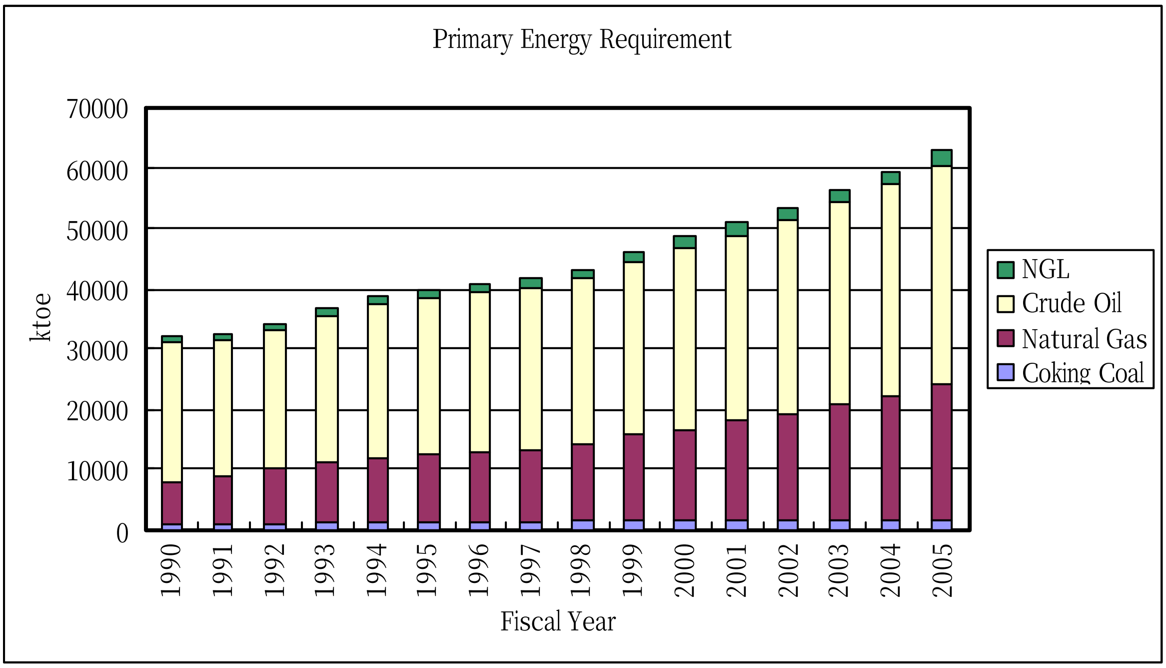
The electric power generation, which recorded 68,000 GWh recorded in 1998/99, is likely to reach 104,518 GWh by 2005/06. As for power source, the major incremental source would be the thermal power, because the hydropower is assumed to grow by a small margin, based on the past trend.

As for the fuel demand for thermal power generation, natural gas will show the highest growth, doubling the demand from 7,675 ktoe in 1998/99 to14,080 ktoe in 2005/06. Fuel oil demand is projected to increase from 4,208 ktoe in 1998/99 to 5,738 ktoe in 2005/05 (up 4.2% per year). Diesel oil demand continues to shrunk. Natural gas maintains around 70% of the share. The share of fuel oil is just under 30%.

(3) Primary Energy Requirement

The primary energy requirement would grow at an average growth rate of 5.6% from 44,064 ktoe in 1998/99 to 64,675 ktoe in 2005/06. The energy with the highest growth rate is natural gas, whose demand is likely to reach 22,610 ktoe by 2005/06 at the average growth rate of 8.6%, which demand jump 1.7 times over the 1998/99 record of 12,799 ktoe to reach 22,610 ktoe by 2005/06, at an average growth rate of 8.6%. The growth of crude oil demand is projected to be 4.1%. As a result, the share held by natural gas is expected to rise to 35% in 2005/06 from 29 % in 1998/99. On the other hand, the share of crude oil will fall to 56% from 62%.

Figure 5.3.4 Primary Energy Requirement



5.4 Applied Analyses: Macroeconomic-Energy Demand Forecasting Model Simulation

As an integrated application, the macroeconomic-energy demand forecasting model (macroeconomic-energy integrated model) was used for the analysis of ERSAP, crude oil price, domestic energy price, technology, and energy substitution. The results are summarized in Table 5.4.1. They show that the impacts of ERSAP and the potential of energy saving technology are large among others. The impact of 1% change in crude oil price in a year on GDP in-mid term is only 0.014%. However, it means if the crude oil price temporarily doubled for one year, it could have the force to increase the GDP by 1.4 % in mid-term. As for the domestic energy prices, the impact of electricity price is negligible, while the impact of the price rise of petroleum products is slightly positive for GDP. One example of the analysis of price elasticity and cross price elasticity is in Table 5.4.2. As in this example, the simulation results of cross price elasticity shows that they are mostly negligible. It means that the price control of a fuel is not an efficient policy as a measure to control the consumption of its substitute.

Table 5.4.1 Summary of Sensitivity Analysis

1% Increase in	Impact to GDP (Same year)	Impact to GDP (5 Years Later)	Impact to Energy Consumption (Same Year)	Impact to Energy Consumption (5 Years Later)
Structural Reform	0.87%	0.68%	0.4%	0.57%
Crude Oil Price	0.0039%	0.0139%	0.001%	-0.04%
Electricity Price	-0.0014%	0.0001%	0.0081%	0.0027%
Petroleum Product Price	0.0023%	0.0054%	-0.0448%	-0.0153%
Energy Saving by Technology	0.03%	1.09%	-0.98%	-0.338%

Table 5.4.2 Price Elasticity and Cross Price Elasticity
(Electricity vs Petroleum Products)

Price Change 1% in	Consumption Change of Electricity in %	Consumption Change of Petroleum Products in %
Electricity	-0.0331	0.0249
Petroleum Products	0.0000722	-0.0717

6 Energy Supply Planning Model

6.1 Purpose and Model Function

6.1.1 Purpose

The purpose of the supply-planning model is to optimize energy supply balance for energy policy decision-making. The future demand is prepared in the energy demand forecasting model. And shortage and surplus of the energy supply balance is processed in line with the prepared procedures (export for energy supply-surplus and import for energy supply-shortage). During that time, the energy balance is made up for converging to the maximum profit of energy supply side. The energy supply-planning model (ESPM) aims to optimize the objectives, concerning policy by using the energy prices and demand, estimated in the energy demand-forecasting model.

6.1.2 Function

The forecasting and analysis procedures in the energy economic model, which is built up, are performed in macro economic model, energy demand forecasting model, energy supply planning model and environmental impact analysis model. The Energy Supply Planning Model is calculated after the energy demand forecasting model, and collecting the data of energy supply capacity, energy conversion factors and energy prices and costs.

6.2 Model Concept

The Energy Supply Planning Model consists of six EXCEL worksheets. The role of each worksheet is described in the below table. The data output from a worksheet, starting from the price and cost sheet, is processed to the sheet in the next row, which ends with the primary energy supply sheet.

Table 6.2.1 EXCEL Worksheet in ESPM

Sheet	Contents
Price and Cost sheet (PIM)	Price and Cost are estimated in the sheet
Input sheet (LIM)	All data are input in the sheet
LP model sheet (LPM)	The sheet is handled by Solver.
Energy balance sheet (EBT)	The sheet is one of the outputs.
Growth rate sheet (GRT)	The sheet is growth rate of EBT sheet
Primary energy supply sheet (PEC)	The sheet is one of the outputs.

Regarding ESPM, the model uses linear programming method (LP method) in LPM sheet (Other sheets do not use LP method). The model in LPM sheet consists of an objective function, variables and constrains. The variables are prepared for all supply and consumption items per energy for targeted years. The constraints give some limitation to the variables. For each constraint, a feasible range for the variable is generated, and LP model searches the optimum solution in the range. The objective function is set in order to search the maximum profit by the LP model.

Table 6.2.2 Components of LP Model in ESPM

Components	Items
Constraints	Upper limit, Lower limit, Balance constraints
Variables	Initial-stock, Production, Import, Bought, Receivable Domestic demand, Export, Bunker oil, Payable, Finial stock
Objective function	Prices & Cost, Income, Expense, Profit

Energies sectors in the model are defined as the following table. Number of the energies is 30

Table 6.2.3 Energies and Power Generating Sector

Items	Energies and Power generating sector
Coal sector	Coal, Coke
Gas sector	Natural Gas, NGL, LPG, LNG
Oil sector	Crude oil, Refinery gas、LPG (RF)、Gasoline、Jet fuel、Kerosene、Diesel、Fuel oil, Naphtha、Lubricants & additives、Bitumen、Petroleum coke, Non specified products
Power sector	Power distribution, Hydro, Gas combined, Gas Turbine, Diesel engine, Steam-coal Steam-Fuel oil, Solar-Wind-Others
Renewable	Renewable

In the model, five items including Initial-stock, Production, Import, Bought and Receivable, are defined as supply items. Seven items including Sales, Export, Bunker, Payable, Transformation, Energy own use and Final- stock, are defined as the consumption items. These items are generated by the following expression.

Initial-Stock+production+Import+Bought +Receivable
-（Sales+Export+Bunker +Payable＋Transformation+Own use
+Final-Stock）= 0

6.3 Output Information

(1) Consumption

Domestic demand, Export, Bunker oil, Payable, and Transformation are arranged as energy consumption items. The total of consumption meets to the total of supply. Domestic demand, Export, Bunker oil and Payable in the consumption items may have values in the upper limit. Then it is possible to analyze the values of Domestic demand, Export, Bunker oil and Payable, comparing to the values in the upper limit.

Table 6.3.1 Example for Consumption Items

ITEMS 1	ITEMS 2	SECTORS	UNIT	1998	1999	2000	2001	2002	2003	2004	2005
Consumpti	Solution	Domestic demand	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Export	KTON	2,934.0	2,351.0	2,130.0	1,845.0	1,506.0	1,113.0	665.0	155.0
		Bunkers	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Payable	KTON	13,280.4	15,621.2	16,000.0	15,962.7	15,700.7	15,401.1	15,062.9	14,681.7
		Transformation	KTON	25,641.8	27,180.8	27,970.0	28,199.0	28,145.1	28,088.6	28,029.3	27,967.5
		Own use	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	KTON	41,856.2	45,153.0	46,100.0	46,006.7	45,351.8	44,602.7	43,757.2	42,804.2
	UpperLimit	Domestic demand	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Export	KTON	2,934.0	2,351.0	2,130.0	1,845.0	1,506.0	1,113.0	665.0	155.0
		Bunkers	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Payable	KTON	U	U	U	U	U	U	U	U
	Sufficient ra	Domestic demand	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Export	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		Bunkers	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Payable	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(2) Supply

Initial-Stock, Production, Import, Bought, Receivable and Final-Stock are arranged as energy supply items. The total supply meets to the total consumption. Production, Import, and Bought in the supply items may have upper limit values. Then, it is possible to analyze the values of Production, Import and Bought, comparing to the values in the upper limit.

Table 6.3.2 Example for Supply Items

ITEMS 1	ITEMS 2	SECTORS	UNIT	1998	1999	2000	2001	2002	2003	2004	2005
Supply	Solution	Initial-Stock	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Production	KTON	35,796.2	39,053.0	40,000.0	39,906.7	39,251.8	38,502.7	37,657.2	36,704.2
		Import	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Bought	KTON	6,060.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0
		Receivable fm Differer	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Final-Stock	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	KTON	41,856.2	45,153.0	46,100.0	46,006.7	45,351.8	44,602.7	43,757.2	42,804.2
	UpperLimit	Capacity	KTON	40,000.0	40,000.0	40,000.0	40,000.0	40,000.0	40,000.0	40,000.0	40,000.0
		Production	KTON	39,516.0	39,496.0	40,034.0	40,532.0	40,999.0	41,441.0	41,865.0	42,276.0
		Import	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Bought	KTON	6,060.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0	6,100.0
		Receivables	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sufficient ra	Capacity	%	89.5	97.6	100.0	99.8	98.1	96.3	94.1	91.8
		Production	%	90.6	98.9	99.9	98.5	95.7	92.9	89.9	86.8
		Import	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Bought	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		Receivables	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Supply rate	Production rate	%	85.5	86.5	86.8	86.7	86.5	86.3	86.1	85.7
		Import rate	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Bought rate	%	14.5	13.5	13.2	13.3	13.5	13.7	13.9	14.3
		Receivable rate	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(3) Profitability

Income, Expense and Profit are arranged in Profitability. The profitability of price and cost items are displayed blow. And profit per unit is calculated in this sheet. ROI (Return on investment) is an index that shows the profitability on the total investment. In the model, however, ROI is calculated as Profit per unit / production cost * 100.

Table 6.3.3 Example for Profitability Items

ITEMS 1	ITEMS 2	SECTORS	UNIT	1998	1999	2000	2001	2002	2003	2004	2005
Profitability	Profit	Income	millionLE	12,026.0	13,773.4	14,425.6	14,749.4	14,866.7	14,922.6	14,918.4	14,849.0
		Expense	millionLE	9,739.9	11,022.2	11,584.7	11,892.0	12,042.7	12,156.2	12,234.2	12,274.8
		Profit	millionLE	2,286.2	2,751.2	2,840.9	2,857.4	2,823.9	2,766.4	2,684.2	2,574.2
	Price & Uni	Sales price of Domesti	LE/TON	374.3	417.6	430.1	442.3	454.3	466.2	478.1	490.3
		Sales price of Export	LE/TON	374.3	491.3	505.9	520.4	534.5	548.5	562.5	576.8
		Sales price of Bunkers	LE/TON	397.7	417.6	430.1	442.3	454.3	466.2	478.1	490.3
		Invoice cost	LE/TON	280.8	294.8	303.6	312.2	320.7	329.1	337.5	346.1
		Import cost	LE/TON	225.6	320.2	449.4	480.8	513.9	548.9	586.1	625.6
		Bought cost	LE/TON	252.3	264.9	272.8	280.6	288.2	295.8	303.3	311.0
		Production cost	LE/TON	229.4	240.9	248.0	255.1	262.0	268.9	275.7	282.7
		Profit per unit	LE/TON	54.6	60.9	61.6	62.1	62.3	62.0	61.3	60.1
		ROI	%	23.8	25.3	24.8	24.3	23.8	23.1	22.2	21.3

(4) Primary Energy Consumption

Primary energy consumption is defined as the following expression.

Indigenous production + Import + Bought – Partner – Export -Bunkers

In the following table, the energies with a plus sign are the net consumption in the domestic market and the energies with a minus sigh are the net export. The total from the energies after converting to toe is displayed in TOE table as the primary energy consumption in Egypt.

Table 6.3.4 Example for Primary Energy Consumption

ITEMS 1	SECTORS	UNIT	1998	1999	2000	2001	2002	2003	2004	2005
Primary Energy Consu	Coal	KTON	1,614.1	1,953.5	2,000.0	2,050.7	2,105.6	2,166.2	2,231.0	2,300.0
	Coke	KTON	-246.0	-464.0	-464.0	-464.0	-464.0	-464.0	-464.0	-464.0
	Crude oil	KTON	25,641.8	27,180.8	27,970.0	28,199.0	28,145.1	28,088.6	28,029.3	27,967.5
	Natural gas	KTON	10,698.7	12,082.2	12,427.4	12,791.2	13,174.2	13,575.2	13,996.2	14,435.2
	NGL	KTON	1,506.4	1,701.2	1,749.8	1,801.0	1,854.9	1,911.4	1,970.7	2,032.5
	FD-LPG	KTON	1,005.6	1,135.7	1,168.1	1,202.3	1,238.3	1,276.0	1,315.6	1,356.8
	LPG distribution	KTON	733.0	715.2	862.4	1,018.7	1,186.7	1,364.0	1,556.4	1,770.2
	LNG	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feedstock	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	RF-Gas	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	RF-LPG	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline	KTON	144.5	153.9	200.3	278.0	372.0	463.0	551.0	639.0
	Jet fuel	KTON	-396.4	-439.5	-456.6	-457.0	-450.0	-443.0	-437.0	-431.0
	Kerosene	KTON	0.0	-147.0	-286.0	-420.0	-548.0	-571.0	-640.0	-703.0
	Diesel	KTON	1,577.7	1,497.4	1,875.5	2,428.0	3,113.0	3,872.0	4,712.0	5,644.0
	Fuel oil	KTON	-3,347.7	-3,644.8	-3,501.8	-3,065.1	-2,451.9	-2,336.0	-2,350.0	-2,353.0
	Naphtha	KTON	-2,849.4	-2,960.4	-3,046.3	-3,075.0	-3,075.0	-3,075.0	-3,075.0	-3,075.0
	Lubricants & additives	KTON	90.0	85.8	89.5	97.0	108.0	118.0	128.0	139.0
	Bitumen	KTON	108.3	119.3	116.8	134.0	162.0	194.0	229.0	267.0
	Petroleum Coke	KTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Non specified products	KTON	208.1	372.7	379.7	389.0	400.0	411.0	422.0	433.0
	Power distribution	GWh	0.0	80.3	1,503.1	2,917.9	4,516.0	7,848.3	11,447.4	16,479.7
	Power Hydro	GWh	15,000.0	15,282.0	15,550.0	15,804.0	16,047.0	16,278.0	16,500.0	16,713.0
	Power Gas combined	GWh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Coal steam	GWh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Gas turbine	GWh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Diesel engine	GWh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Fuel oil steam	GWh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Power Solar Wind Othe	GWh	25.0	67.0	445.0	914.0	1,289.0	2,048.0	3,407.0	3,500.0
	Renewable	KTON	99.0	99.0	100.0	282.0	283.0	283.0	284.0	285.0

6.4 Simulation Results

For the simulation of energy supply policy, several scenarios are examined by use of the Energy Supply Planning Model. The two indicators of indigenous energy supply and CO2 emission are prepared for the examination of energy strategy. Policy variables are technical changes, crude oil bought, natural gas production, refinery capacity and GCC capacity.

Table 6.4.1 Scenario and Results (LP Model)

Scenario	Contents
Base case	For forecasting future energy balance (2005) including the current energy policies, the Base case should be prepared. The current capacities and forecasting demand are set as the Base case. **(Results)** LPG, Gasoline and Diesel oil balances are short. The energies are imported to meet their demand.
Scenario 1	For resolving Gasoline, Diesel and LPG shortage, the yields of LPG, Gasoline, Diesel are 10% up, the yields of Fuel oil (7%) and Naphtha (11%) are down in 2001 **(Results)** Gasoline and Diesel shortage are mostly not resolved.
Scenario 2	For decreasing import of petroleum products, this scenario is assumed to increase crude oil from partners at 20% to 2000. **(Results)** LPG, Gasoline and Diesel still have the supply shortage.
Scenario 3	For decreasing import of petroleum products, this scenario is assumed to increase crude oil from partner at 20% to 2000 and yields at 10% up. **(Results)** Diesel still have the supply shortage. But Gasoline shortage is resolved.
Scenario 4	This scenario makes a plan to install a LNG plant consumed Natural gas and makes foreign trade surplus increase. **(Results)** By exporting LNG, Egypt can increase the profit at level of 9% to the Base case.
Scenario 5	Renewable energies is supplied with 285 kton in 2005, and the renewable energies substitute LPG domestic demand. As the results, it is expected that LPG import decreases. **(Results)** Renewable energies is supplied with 285 kton in 2005 and is consumed in residential sector. LPG demand is decreased as much as the supply of renewable energy

The following table is the comparison with strategy indicators of the base case, and Scenario 1 to 5. The strategy indicators are value added, foreign trade and CO_2 emission.

Table 6.4.2 Base Case and Scenario 1 to 5

Scenarios	Value added in Energy sectors (million LE)	Energy foreign trade balance (million LE)	CO_2 emission From all energies (Million ton as CO_2)
Base case	8,749	-4,819	145.7
Scenario 1 Yields	8,819	-4048	145.7
Scenario 2 Bought	8,858	-4562	145.8
Scenario3 Yield+Bought	8,930	-3763	145.8
Scenario 4 LNG	9,533	-1618	145.7
Scenario 5 Renewable	8,818	-4732	145.7

Comments	Profit in LP model = Value Added	Energy Export - import - Bought	CO2 emission From-En- model-LP

1) **Value added**: Defined by profit in LP model

The value added of each scenario is higher than the base case. And the good conditions of the value added are Scenario 3 and 4.

2) **Foreign trade** : Defined by 'Export-Import-Bought' Foreign trade of scenarios 3 and 4 are also the good conditions.

3) **CO2 emission** : Come from Environmental model

CO2 emission of Scenario 2 and 3 is comparably rather high than other scenarios. But the increase is small.

4) **Information for Energy Supply Policy**

Scenario 3 and 4 are attractive Scenarios for Egypt, if the CO2 emission of the scenarios is permitted by the regulation of Egypt. The Scenario 3 and/or 4 should be selected as Egyptian energy policy from 2000 to 2005.

Table 6.4.3 Comparison of the Base case and Scenarios 3 and 4 (2005/06)

Solution	Unit	Base Case	Scenario 3	Scenario 4	Scenario 3 + 4
Crude oil production	KTON	40,000	40,000	40,000	38,205
Crude oil Bought	KTON	6,100	7320	6100	7,320
Natural gas production	KTON	18,355	18,371	23,981	23,981
LNG production	KTON	0	0	5,000	5,000
GCC Generation	KTON	46,148	46,184	46,148	46,148
LPG import	KTON	1,105	855	470	169
Gasoline import	KTON	381	0	276	0
Diesel import	KTON	3,928	2,963	3,838	3,104
Profit	Million LE	8,749	8,930	9,533	9,566

The right column of '3+4' is one scenario that is implemented under the conditions of scenario 3 and scenario 4.

The increase of crude oil from partners and LNG production are required in the scenarios 3 and 4. The energy policy will make the profit with 9.3% up to the base case.

As further energy policy, substitution of diesel and LPG demand can be considered. This is another scenario that LPG residential demand and diesel transportation demand be substituted by natural gas.

7. Environmental Analysis Model

7.1 Environmental Issues and Strategy

Egypt is known as the first developing country to give a great attention to environmental problems. But judging from the present situation of air pollution in Egypt, the more improvement in the air environment is needed. Concentrations of air pollutants in Greater Cairo exceed the WHO guideline and the former U.S. standard.

Table 7.1.1 Concentrations of Air Pollutants in Greater Cairo (microgram/m^3)

Pollutant	Concentration		U.S. Standard		WHO Guidline	
Sulfur Dioxide	40-156	annual mean	80	annual mean	40-60	annual mean
Particulate matter	349-857	annual mean	75	annual mean	60-90	annual mean
Nitrogen Oxides	90-750	hourly mean	100	annual mean	320	hourly mean(N2O)
Carbon Monoxide	1,000-18,000	hourly mean	40,000	hourly mean	10,000	8-hour mean
Lead	0.5-10	annual mean	2	quartly mean	0.5-1.0	annual mean
Ozone	100-200+	hourly maximum	235	hourly maximum	150-200	hourly mean

Table 7.1.2 Maximum Limit of Outdoor Air Pollutants (microgram /m^3)

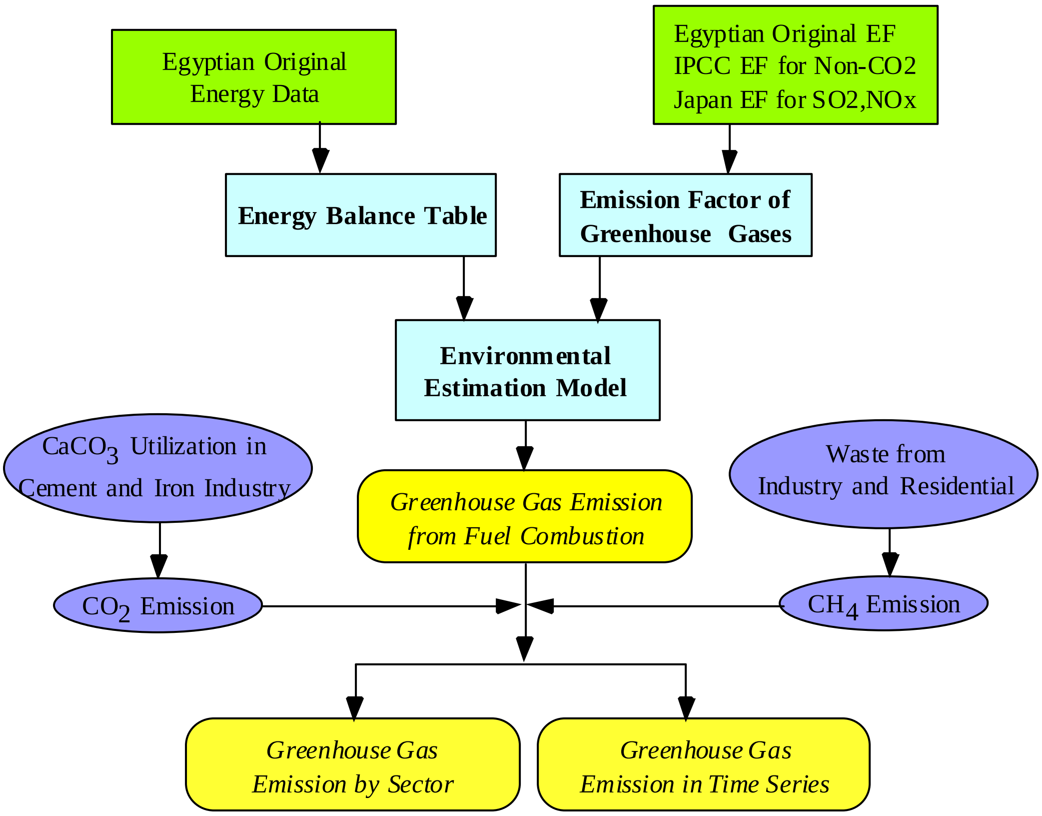
POLLUTANT	MAXIMUM LIMIT	EXPOSURE PERIOD	Japanese Srandard
Sulphur Dioxide	350 150 60	1 hr 24 hrs 1 year	285 114
Carbon Monoxide	30 Milligrams/cubic meter 10 Milligrams/cubic meter	1 hr 8 hr	12.5 10
Nitrogen Dioxide	400 150	1 hr 24 hrs	 123
Ozone	200 120	1 hr 8 hr	128
Suspended Particles Measured as Black Smokes	150 60	24 hrs 1 year	
Total Suspended Particles (TSP)	230 90	24 hrs 1 year	
Respirable Particles (Pm 10)	70	24 hrs	100
Lead	1	1 year	

The Environmental Law (Law Number 4 of 1994) reshaped newly the Egyptian Environmental Affaires Agency (the EEAA) and gave the authority to formulate the national plan with the projects included the protection of the environment and to implement of such a national plan. This law has the standards on the emissions of air pollution. Thus the system of protection of the environment was improved and reinforced.

7.2 Environmental Analysis Model and the Results

Figure 1 shows the flow chart to estimate the GHGs emissions.

Figure 7.2.1 Flow Chart for Estimating Emissions of GHGs



The study team made "Energy Balance Table" and "Emission Factors of GHGs" based on the Egyptian original data as much as possible. Next the team estimated 6 GHGs and SO_2 emissions using "Environmental Analysis Model" and these data. At last the team estimated the total GHGs emissions adding the CO_2 emissions from consuming limestone in cement and iron industry and CH_4 emissions (CO_2 equivalent) from wastewater/sludge and solid disposal place. For the information about limestone in cement and iron industry, the team depended upon the study done by the Environmental Protection Agency in Japan.

(1) Energy Balance Table made by OEP

OEP makes "Energy Flow" where focus was chiefly applied to oil every year. In this project the team made "Energy Balance Table" suitable for estimating GHGs emissions. This table is composed of the sector classification fom production to consumption of energy and the energy source classification (28 energy sources). Unit value of energy is KTOE (kilo-ton of oil equivalent).

(2) Emission Factors made by OEP

For CO_2 emission factors, the team made the Egyptian original emission factors using the net calorific value in Egyptian energy sources based on the IPCC Guideline.

Table7.2.1 Emission Factors of CO_2 in Egypt

	IPCC Data			Egyptian data			
	TC/TJ	TJ/T	T-CO_2/T	TOE/T	T-CO_2/TOE	T-C/TOE	T-C/TJ
Coke Oven Coke	29.50	29.31	3.1701	0.7000	4.5287	1.2351	29.5
Natural Gas	15.30	46.55	2.6115	1.1110	2.3506	0.6411	15.3
Crude Oil	20.00	41.09	3.0135	0.9950	3.0286	0.8260	19.7
Liquefied Petroleum Gases	17.20	47.31	2.9837	1.1250	2.6522	0.7233	17.3
Natural Gas Liquids	17.20	46.18	2.9124	1.1030	2.6405	0.7201	17.2
Naphtha	20.00	45.01	3.3007	1.1030	2.9925	0.8161	19.5
Motor Gasoline	18.90	44.80	3.1046	1.1030	2.8147	0.7677	18.3
Kerosene type Jet Fuel	19.50	44.59	3.1882	1.0860	2.9357	0.8006	19.1
Kerosene	19.60	44.75	3.2160	1.0860	2.9614	0.8076	19.3
Gas/Diesel Oil	20.20	43.33	3.2093	1.0660	3.0106	0.8211	19.6
Residual Fuel Oil	21.10	40.19	3.1094	0.9720	3.1989	0.8724	20.8
Lubricants	20.00	40.19	2.9473	0.9720	3.0322	0.8270	19.8
Refinery Gas	18.20	48.15	3.2132	1.1250	2.8562	0.7790	18.6
Petroleum Coke	27.50	31.00	3.1258	0.7400	4.2241	1.1520	27.5
Non-specified Petroleum Products	20.00	40.19	2.9473	0.9720	3.0322	0.8270	19.8

(Note) TC/TJ and TJ/T in IPCC Data are the numbers estimated by IPCC and we can find these data in IPCC guideline. T-CO_2/T in IPCC Data is obtained from calculating the following calculation: (TC/TJ * TJ/T * (44/12)/1000). In order to obtain the Egyptian original emission factor, we must adjust IPCC numbers by the Egyptian original net calorific value of each energy sources.

TOE/T in Egyptian Data is the net calorific value in Egypt. T-CO_2/TOE is calculated from the following calculation: ((T-CO_2/T) / (TOE/T)) and T-C/TOE from (T-CO_2/TOE * (12/44)). Finally, T-C/TJ is calculated from the following calculation type; (T-C/TOE / 41.868 * 1000), in which 41.868 is the conversion factor from KTOE to TJ.

(Source) "IPCC Guidelines for national Greenhouse Gas Inventories, 1996" and OEP "Annual Energy Report"

For SO_2 and NO_x, the team made the emission factors using data studied by the Science and Technology Agency in Japan based on the Egyptian original data. For other GHG excluding these three gases, the team adopted the IPCC Guideline due to the lack of data.

(3) CO_2 and CH_4 Emissions from Industrial Process and Wastes

CO_2 emissions from limestone utilized in the cement and iron industry is estimated based on the emission factors from the Japanese Environmental Protection Agency and the production data from Egyptian industry. CH_4 emissions are estimated by OEP based on the IPCC Guideline.

7.3 Estimated GHG Emissions and the Implications

(1) Structure of GHG Emissions in Egypt

Total amount of CO_2 emissions is 103.82 million ton (CO_2 equivalent) and the share of emissions in the power utility is 34.4%, transport is 25.9%, industry is 25.6% and the others is 10.0% in FY1998.

If considering CO_2 emissions from limestone in the cement and iron industry and CH_4 from wastewater and solid disposal, the industry sector becomes the biggest emission sector and hereafter power utility, transport and other sectors continue.

It is clear that CO_2 emissions from the industrial process using limestone in the cement and iron industry are very important. It is necessary to estimate exactly this kind of CO_2 emissions in the future, too.

For GHG excluding CO_2, the team estimated the emissions based on the fuel combustion and unit values are 1000 ton of each gas. The shares of industry and power utility are big in SO_2 emissions and the shares of transport is big in NO_x, CH_4, CO and NMVOC emissions. These numbers show that the countermeasures in the transport sector are important in the non-CO2 emissions.

Table7.3.1 Non-CO_2 Emissions in 1998/99

1998	SO_2 Emission ($KTSO_2$)	NO_x Emission ($KTNO_x$)	CH_4 Emission ($KTCH_4$)	N_2O Emission (KTN_2O)	CO Emission (KTCO)	NMVOC Emission (KTNMVOC)
Industry	125.92	48.15	1.18	0.19	8.87	0.95
Transportation	41.39	229.75	3.92	0.23	1320.88	250.76
OtherSector	5.84	5.04	1.52	0.09	3.57	0.79
Electricity	123.01	80.50	0.87	0.14	9.16	1.61
Energy Sector	17.20	19.70	0.14	0.03	0.92	0.07
Total	313.35	383.14	7.63	0.68	1,343.40	254.17

(2) Historical Analysis of GHGs Emissions in Egypt

Energy consumption between FY 1981 and FY 1998 increased by 4.89% annually. On the other hand, CO_2 emissions grew by 4.51% annually and the coefficient of CO_2 to energy consumption was 0.92. This situation was affected by the decrease of energy intensity through fuel switching from oil to natural gas.

Table 7.3.2 Comparing Energy Consumption and CO_2 Emissions

	Fossil Fuel Consumption (TJ)	CO_2 Emision ($MtCO_2$)	Fossil Fuel Consumption 1981/82=100	CO_2 Emision 1981/82=100
1981/82	647,677	46.4	100.0	100.0
1982/83	732,270	52.4	113.1	112.9
1983/84	816,164	58.1	126.0	125.2
1984/85	883,495	62.6	136.4	134.9
1985/86	903,869	63.2	139.6	136.2
1986/87	969,229	67.8	149.6	146.0
1987/88	1,025,829	71.4	158.4	153.9
1988/89	1,027,561	71.3	158.7	153.7
1989/90	1,080,036	74.7	166.8	161.0
1990/91	1,114,327	76.8	172.0	165.6
1991/92	1,116,497	76.9	172.4	165.7
1992/93	1,111,391	75.6	171.6	162.9
1993/94	1,107,880	74.8	171.1	161.2
1994/95	1,162,162	78.2	179.4	168.4
1995/96	1,235,918	83.3	190.8	179.4
1996/97	1,288,791	87.0	199.0	187.4
1997/98	1,400,527	94.7	216.2	204.1
1998/99	1,457,404	98.2	225.0	211.6
1999/00	1,542,000	103.1	238.1	222.2
2000/01	1,639,367	109.3	253.1	235.4
2001/02	1,746,421	116.0	269.6	250.0
2002/03	1,864,156	123.5	287.8	266.0
2003/04	1,994,121	131.7	307.9	283.7
2004/05	2,137,586	140.7	330.0	303.2
2005/06	2,296,045	150.7	354.5	324.8
Average Growth Rates				
(1998/99)/(1981/82)	4.89	4.51	4.89	4.51
(2005/06)/(1998/99)	6.71	6.31	6.71	6.31
(2005/06)/(1981/82)	5.41	5.03	5.41	5.03

There is the big difference in the tendency of non-CO_2 emissions between before 1990s and after 1990s. Although before 1990s the difference of changes in each GHGs emission was small, after 1990s the difference of changes expanded. The growth rate of SO_2 emissions became small due to the fuel switching to natural gas in power utility and on the other hand the growth rate of CO, NMVOC, NO_x and CH_4 emissions became bigger than before due to the level of the emission factor unchanged in transport sector, which has a big share in these GHGs emissions.

(3) Relationship between Economic Growth, Population and GHG Emissions

From 1981/82 to 1998/99, GDP in Egypt has increased from 117.6 Billion LE to 268.3 Billion LE, by about 5.0% annually. In the same period, the amount of CO_2 emissions has increased by 4.5% annually. The elasticity of CO_2 to GDP is 0.91.

Generally speaking on the relationship between GDP and CO_2 emission, until the early 1990's, Egyptian economy seemed to be stagnated, but after then its economy has recovered rapidly. Reflecting this situation, the energy consumption stagnated; especially oil consumption reached the ceiling at the end of 1980's. On the other side, gaseous fuel consumption has increased smoothly. After the early 1990's, energy consumption, both oil and gas, has increased smoothly along with the economic recovery. CO_2 emission has reflected the economic activity through the changes of the fossil fuel. CO_2 emissions have the intimate relations with the emission factors of GHG, and the structural changes from oil to gas means the reduction of the emission factors of GHG. As a result, the economic activity gave the influence on the structural changes in the energy consumption sources and through this gave the reduction influence on the CO_2 emission factors. The elasticity of CO_2 to GDP came under1.

The relationship of GHG emissions and population is as follows. The index curve of population is something like line going up in the right side, but the index of GHGs emission has been fluctuated very much. The tendency of fluctuation has strongly reflected energy consumption and emission factor as mentioned before. Although the intensity of non-CO_2 per capita shows us the same tendency in case of GHGs emissions per energy, the intensity of CO_2 per capita increases very much due to the unchanging fuel consumption structure (the end of natural gas switching) in 1990s.

8. Database

The Energy Database has two parts, which includes the energy production in Egypt, the primary energy supply and the final energy supply via conversion sectors, called supply side, and energy consumption in each sector and sub-sector, called demand side.

There are two files in this Database. One is energy statistics file that is data input file using physical unit of each fuel, and the other is energy balance file that is converted to "ktoe", oil equivalent value. Both file will be used the model building.

8.1 Data Gathering

Several yearbooks and annual reports concerning energy are published by Central Agency for Public Mobilization and Statistics (CAPMAS), Egyptian Genera Petroleum Corporation (EGPC) and Egyptian Electricity Authority (EEA). The data in those books are summarized and, hence not enough for the model building. The planned model is a short-term projection until 2005. Therefore, the historical data is gathered from 1981 to the latest year available, considering data reliability and consistency. Each data has its own unique reliability, and the regression method will need of 10 to 15 years to obtain reliable formulas. Each formula uses the appropriate term of the data depending on the data reliability and necessity of the data for the formula.

OEP members obtained the data for the supply side through great efforts, from CAPMAS, EGPC, EEA and the old documents from 1981/82 in OEP library. As a result, the data of the supply side is nearly enough for model building.

The electricity Data from EEA annual report, which is thoroughly prepared with great attentions to the detail, is quite enough for the purpose as well.

On the other hand, data acquired for the consumption side is considerably rough. Although the data of the main sector is available, the data of the sub-sectors is not enough to make the model practical and useful for the analysis of the use and tendency of energy in each sub sector.

Since all data of the industry sector is usually summarized as one sector in Egypt,, the production data and the energy consumption data are not separated in each sub sector. In spite of OEP's efforts, such kind of data could not be obtained during the Study. The data source did not have such kind of detailed data but only had limited original data, which are too basic and needed much examination and evaluation to make useful data tables. Besides these data did not cover all sectors. As a result, the industry was treated as only one category containing all industry sectors.

8.2 Energy Flow

The gathered energy data, to be applied in the model building, are verified with the energy flow in Egypt,. Egypt is a petroleum-producing country, and foreign investors are contracted to operate almost all oil and gas fields, resulting in a unique primary energy flow for Egypt. These are found in crude oil, natural gas, condensates and LPG flow.

The energy statistical data is identified in the energy flow and put into the Energy statistical file.

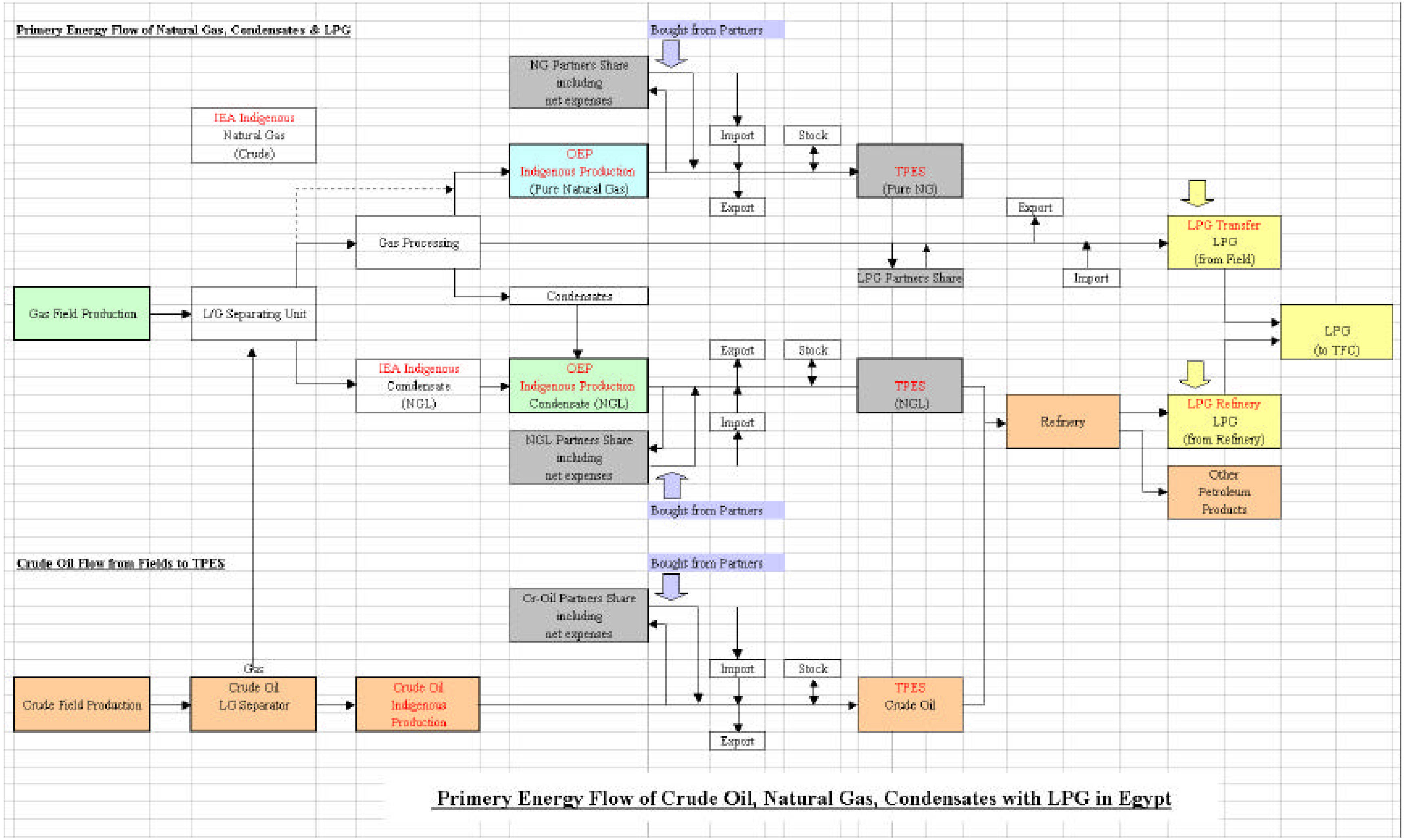
Figure 8.2.1 shows the general primary energy flow in Egypt. It is discussed by both OEP and JICA to get the bilateral recognition of the actual energy flow in Egypt. According to this primary energy flow diagram, every data has its definition. The indigenous production, crude oil, natural gas and condensates are shared between Egypt and "Partners" with contract. Besides, Egypt pays some amount of products to "Partners" as net expenses. Those total is defined as "Partner Share". After that, Egypt buys some amount of the primary energy from "Partners" by FOB. This is defined as "From Partner". Finally, the energy data gets TPES (Total Primary Energy Supply) subtracting import, export, international marine bunker and aviation and stock change.

As for coal, there is a coal flow in Egypt. Coal flow data in the iron and steel industry is still missing; the data cells of coke oven or blast furnace in the iron and steel industry are remained blank in Excel sheet.

Natural gas production is increasing significantly in recent year. "Partners" are also developing gas fields and operating gas fields and gas processing facilities to get LPG. "Partner Share" and "From Partner" are also defined in this flow.

A large amount of natural gas production is expected in Egypt in the near future. Utilizing natural gas for domestic fuel reduces the growth of petroleum products consumption. Also, Egypt has plans to export natural gas to neighboring countries through pipelines. Egypt recently has reached the protocol agreement with Turkey to export LNG in early 2000. The primary energy flow in Egypt will be dramatically changed in several years.

Figure 8.2.1 Primary Energy Flow in Egypt



8.3 Database Configuration

The Database has one pair of Microsoft Excel files for each category. One file uses physical unit, kton/GWh, and the other file uses unified unit, kiloton oil equivalent, "ktoe". It will be easy to maintain these files since these Excel files do not use specially-defined functions or Macro but only use the originally-provided functions and formula in Excel. Also, all data sheets have the same format for an easy access to Energy balance Table and other summarized data table

8.3.1 File List

(1) Original Past Trend Files

Eg_OEP_DBAL_v22.xls (kton / GWh)
Eg_OEP_DBAL_u22.xls (ktoe)

Eg: Egypt
OEP: Organization of Energy Planning
DBAL: Detail Balance
v: Value, Physical unit, kton/GWh
u: Unified unit, ktoe

All files using Physical Unit (kton, GWh) are hereafter called "v" file
All files using Unified Unit (ktoe) are hereafter called "u" file

(2) Modified Past Trend Files for the Model building

Eg_OEP_DBAL_v30.xls (kton / GWh)
Eg_OEP_DBAL_u30.xls (ktoe)

Assumption to Coal and Coke Flow is added because of lack of data

(3) Original Projection Data Files for Data Linkage

By Demand Forecasting Model

Eg_OEP_DBAL_vf_FMT.xls (kton / GWh)
Eg_OEP_DBAL_uf_FMT.xls (ktoe)

By LP Supply Model

Eg_OEP_DBAL_vf_LPT.xls (kton / GWh)
Eg_OEP_DBAL_uf_LPT.xls (ktoe)

(4) Future Projection Data Files by Final Model (Simple E)

(5) Future Projection Data Files by LP Supply Model

Eg_OEP_DBAL_vf_FM**.xls (kton / GWh) Eg_OEP_DBAL_uf_FM**.xls (ktoe)

Eg_OEP_DBAL_vf_LP**.xls (kton / GWh) Eg_OEP_DBAL_uf_LP**.xls (ktoe)

8.3.2 Pair of Files

The Data Conversion to Physical unit to Unified unit, ktoe, is calculated by formulas in "u" file, by this flow from "v" files to "u" files, by using Net Calorific Value of Egypt in "v" file.

Figure 8.3.1 Pair of Files

"v" file Energy Statistics File (kton, GWh) Eg_OEP_DBAL_v**.XLS NCV sheet	⇒	"u" file Energy Balance File (ktoe) Eg_OEP_DBAL_u**.XLS Conversion Formula

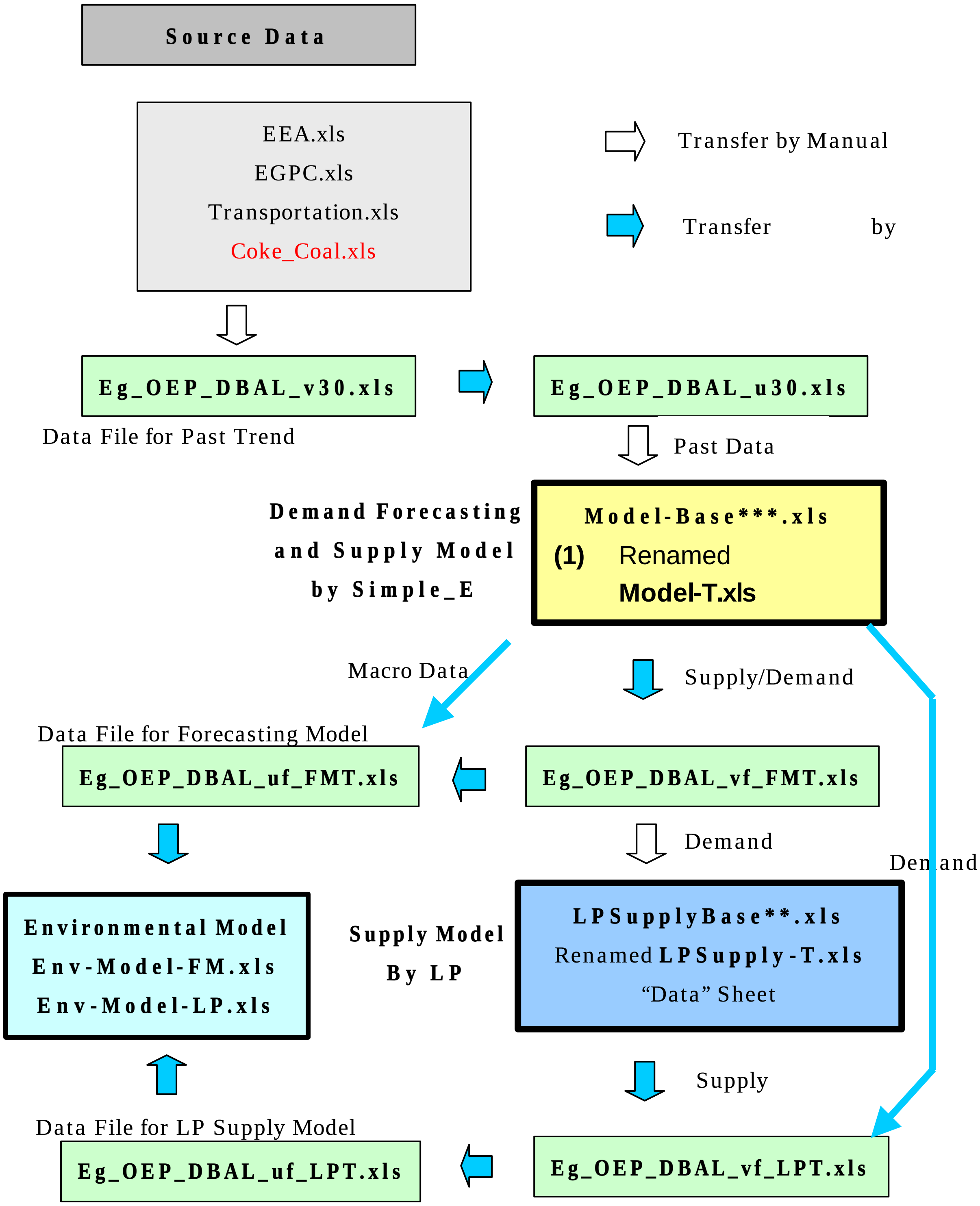
This means "Pare of Files" for one Database.

8.4 Data Linkage

All Data are basically transferred with this Flow. White arrow means Data transfer by manual, and colored arrow means Automatic Data transfer by several formulas.

8.4.1 Data Transfer Flow

Figure 8.4.1 Data Linkage between each File



8.4.2 Inter-reference of each File

(1) **Eg_OEP_DBAL_vf_FMT.xls** refers **Model-T.xls**

This file has direct linkage formulas to **Data_T** sheet in **Model-T.xls**, that gives Demand side data and Supply side data to this "v" file.

(2) **Eg_OEP_DBAL_uf_FMT.xls** refers **Eg_OEP_DBAL_vf_FMT.xls** and **Model-T.xls**

This file has direct linkage formulas to each energy sheet in **Eg_OEP_DBAL_vf_FMT.xls** to make data conversion from physical unit to kiloton oil equivalent unit, "ktoe", and has direct linkage formula to **Data_T** sheet in **Model-T.xls** to obtain the Macro Economic data.

(3) **Eg_OEP_DBAL_vf_LPT.xls** refers **Model-T.xls** and **LPSupply-T.xls**

This file has direct linkage formulas to, **Data_T** sheet in **Model-T.xls** to obtain Demand side data, and has direct linkage formulas to, **Data** sheet in **LPSupply-T.xls** to get Supply side data.

(4) **Eg_OEP_DBAL_uf_LPT.xls** refers **Eg_OEP_DBAL_vf_LPT.xls**

This file has direct linkage formula to each energy sheet in **Eg_OEP_DBAL_vf_FMT.xls** to make data conversion from physical unit to "ktoe".

9. Conclusion

The objectives of the Study are to develop Energy-Economic models (short-term forecasting-simulation models) for Egypt in order to evaluate the impact of public energy policies on its economy and to transfer the technology for building and operating of these models. The Study is for both model building and technology transfer.

9.1 Model Building

(1) Function of Model

The major policy issues to be analyzed are summarized in Table 1.1.1. These policy issues are the targets of our outputs by the energy economic model. The base year and target year of the models are 1998/99 and 2005/06 respectively.

(2) Configuration of Models

Models are comprised of a series of Macroeconomic energy demand forecasting model (Macroeconomic-energy model), Energy supply planning model, Environmental impact analysis model and Database. And models are categorized into models to be developed by econometric tool (Macroeconomic model and Energy supply/demand model) and a model (Energy supply planning model) by linear programming tool (See Figure 1.3.1).

Development of each model was carried out separately. Macroeconomic model and Energy demand forecasting model were linked as one model system, which covers from final energy consumption to primary energy requirement. Energy supply planning model is an optimization model to evaluate maximum benefit of the total energy supply system. As Energy supply planning model involves objective functions and constraints, the model is yet another model system of Macroeconomic energy demand forecasting model. Environment impact analysis model can link both Macroeconomic energy demand and Energy supply planning model through Database as an interface.

Macroeconomic energy demand forecasting model can simulate macroeconomic activities and energy demand by scenario. Energy supply planning model receives the forecast energy demand and can simulate the best mix of energy to be the maximum benefit under the constraints of facilities' capacity. Both models can be used separately or simultaneously through Database.

9.2 Technology Transfer

Workshop for technology transfer was held in each work-in-Egypt. Especially, the long-running workshop in the third work-in-Egypt was carried out concentratively. The contents of the technology transfer include: 1) the theories and concepts underlying individual models, 2) the tools and methods for model building, 3) the technique of building the Energy-Economic model, 4) the energy database and the database development tool, and 5) the model itself and model maintenance.

In general, model building for macroeconomic and energy demand forecasting models is based on the econometric method, and model building for energy supply model are based on the optimization method with the knowledge of linear programming and energy sector. Considering these two different methods, two teams were organized. The first was the team of econometrics, whose principal tool was "Simple-E." The team was comprised of macroeconomics and energy demand forecasting groups. The other team was the engineering team, whose principal tool was LP. The team was comprised of energy supply planning and database groups.

9.3 Main Outputs

(1) Macro-economic/Energy Demand Forecastiong Model

Three price scenarios are used to see the impacts of domestic energy price. The scenarios are; 1) Nominal price constant (low price scenario); 2) Real price constant (base price scenario) and 3) Real price increase 10 % annually (high price scenario). Energy price scenarios described above can say in other words, that is, low price scenario is demand high case and high price scenario is demand low case from the standpoint of the demand side. Base case is the real price constant case.

Table 9.3.1 Main Forecasted Results by Price Scenario

（unit：annual average growth rate %）

	1998/99 value (ktoe)	High price	Base price	Low price
Total Energy Requirement	44,064	5.44	5.64	6.01
Primary Energy Requirement				
Natural Gas	12,799	8.38	8.47	8.64
Crude Oil	27,400	3.79	4.10	4.70
Secondary Energy Requirement				
Petroleum Products	24,057	36.3	3.91	4.46
Power Generation	5,848	6.23	6.33	6.53
Final Energy Demand				
Agriculture	320	3.77	4.39	5.34

Industry	10,775	5.96	6.06	6.21
Transportation	9,113	4.08	4.49	5.37
Residential/Commercial	5,652	4.87	5.16	5.66
Electricity	4,868	6.48	6.59	6.79
GDP		5.77	5.74	5.68
Elasticity to GDP				
Electricity		1.12	1.15	1.20
Total Energy Requirement		0.94	0.98	1.06

In addition, the impact to GDP of 1) structural reform, 2) increase of international crude oil price 3) increase of electricity prices 4) increase of petroleum products prices, 5) advancement of energy saving technology, and 6) price control for energy substitution are examined as sensitivity analyses.

Table 9.3.2 Examples of Sensitivity Analyses

Issues	Simulation Summary
1) Impacts of ERSAP	- Increase in investment (increase in savings and relative decrease in consumption) - Decrease in government consumption (shrink of public sector with privatization) - Impact of energy sector: contribute to the growth, however the magnitude is smaller than other sectors
2) Increase of International Crude Oil Price	- Increase in export revenue - Positive direct impacts on petroleum sector - Positive indirect impacts on non-petroleum sectors - Accompany time lag of several years
3) Increase of Electricity prices	- Increase of growth in energy sector in short term - However, slightly negative impacts on most sectors in mid-term
4) Increase of petroleum products prices	- Negative impacts on electricity and transportation sector - Positive impacts on non-petroleum sectors in mid-term - Increase of revenue of petroleum sector is short-term only
5) Advancement of energy saving technology	- Large increase in investment - Negative direct impact on petroleum sector - In mid-term, positive impacts on all sectors especially industry and transportation - The benefit increase with time
6) Price control for energy substitution	- Cross price elasticity is negligible, implies supply policy will be more effective at current price level

(2) Energy Supply Planning Model

For the simulation of energy supply policy, several scenarios are examined by the Energy Supply Planning Model. The two indicators of indigenous energy supply and CO2 emission are prepared as the energy strategy. Policy variables are technical changes, crude oil bought, natural gas production, refinery capacity and GCC capacity.

Table 9.3.3 Scenario and Results (LP Model)

Scenario	Contents
Base case	For forecasting future energy balance (2005) including the current energy policies, the Base case should be prepared. The current capacities and forecasting demand are set as the Base case. **(Results)** LPG, Gasoline and Diesel oil balances are short. The energies are imported to meet their demand.
Scenario 1	For resolving Gasoline, Diesel and LPG shortage, the yields of LPG, Gasoline, Diesel are 10% up, the yields of Fuel oil (7%) and Naphtha (11%) are down in 2001 **(Results)** Gasoline and Diesel shortage are mostly not resolved.
Scenario 2	For decreasing import of petroleum products, this scenario is assumed to increase crude oil from partners at 20% to 2000. **(Results)** LPG, Gasoline and Diesel still have the supply shortage.
Scenario 3	For decreasing import of petroleum products, this scenario is assumed to increase crude oil from partner at 20% to 2000 and yields at 10% up. **(Results)** Diesel still have the supply shortage. But Gasoline shortage is resolved.
Scenario 4	This scenario makes a plan to install a LNG plant consumed Natural gas and makes foreign trade surplus increase. **(Results)** By exporting LNG, Egypt can increase the profit at level of 9% to the Base case.
Scenario 5	Renewable energies is supplied with 285 kton in 2005, and the renewable energies substitute LPG domestic demand. As the results, it is expected that LPG import decreases. **(Results)** Renewable energies is supplied with 285 kton in 2005 and is consumed in residential sector. LPG demand is decreased as much as the supply of renewable energy

(3) Environment Impact Analysis Model

The environment model is based on engineering method. It uses "Energy Balance Table" and "Emission Factors of GHGs," which are prepared based on the Egyptian original data as much as possible. The model is linked with the macroeconomic energy demand forecasting model and the energy supply planning model. The model receives the related results from these models and calculates the GHG emission automatically.

Table 9.3.4 Scenario and the Results (Environmental Model)

Scenario	Simulation Results
Base Case (GHG emission)	1) CO_2 emission by sector: electricity (34%), transportation (26%), industry (26%) Taking into consideration of CH_4 emitted from wastewater / sludge and solid waste, maximum emission source is the industrial sector which account for 32 % in CO_2 equivalent. 2) Emission of NOx, CO, N_2O, CH_4 and NMNOC: Transportation sector is responsible for the greater part of emissions. 3) Industrial policy and transportation policy are the key for improving environmental issue.

(4) Database

Database was constructed and the energy flow of Egypt was examined based on IEA format. The purpose of Database is to offer the energy data to other models and to consolidate the result of the model. In Database, the Microsoft Excel is used as a basic tool to be used transparently with other models.

The formulas used in Database uses general functions prepared in Microsoft Excel, does not use any special defined functions and Macro commands. Therefore, the flow of the calculation was not especially controlled in Database, and all formulas are calculated simultaneously by default of Microsoft Excel to realize a high-speed data link.

9.4 Recommendations

(1) Establishment of Data Gathering System

The model requires data to cover a wide range of characteristics. In order to improve the accuracy of model outputs, it is necessary to steadily collect a wide range of data related to industrial activities and energy supply/demand. It requires much time and fund to establish classified statistics, of which the public sector is expected to play an important role for the establishment and maintenance. The arrangement of organization/constitutions including laws and regulations is highly recommended.

(2) Maintenance of Model

The model does not consist of "Black Box" system and differs from models distributed by international organizations and institutions. The model structure is flexible and transparent. The model can be modified or added if necessary. On the other hand, it is imperative to familiarize model treatment and maintenance. When new data is added periodically, it is necessary to fully evaluate the consistency of the data concerning historical trends and energy flow as well as the external and internal variables.

(3) Application to Medium/Long Term Issues

The model is built for short- to medium-term simulation model, and many explainable variables are endogenously treated. If the model is requested to be used as a medium- to long-term model, it is desirable to input the long-term development plan of energy facilities as external variables.

(4) Application to Energy Policy

When the model is applied to certain energy policies, the step-by-step method is recommendable. The application method should be reliable and reasonable for applying model block and function by turns. For instance, energy demand forecasting part should be applied firs, followed by price part and energy supply planning part.