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

Manual

January, 2001

The Institute of Energy Economics, Japan (IEEJ)

Model Manual

M-1 Macroeconomic Model

M-2 Energy Demand Forecasting Model

M-3 Energy Supply Planning Model

M-4 Environmental Impact Analysis Model

Operation Manual

O-1 Simple E. Operation Manual

O-2 Large Scale Solver LP Operation Manual

O-3 Database Operation Manual

M-1

Model Manual
of
Macroeconomic Model

JICA Study Team

The Institute of Energy Economics, Japan

M-1

Model Manual of Macroeconomic Model

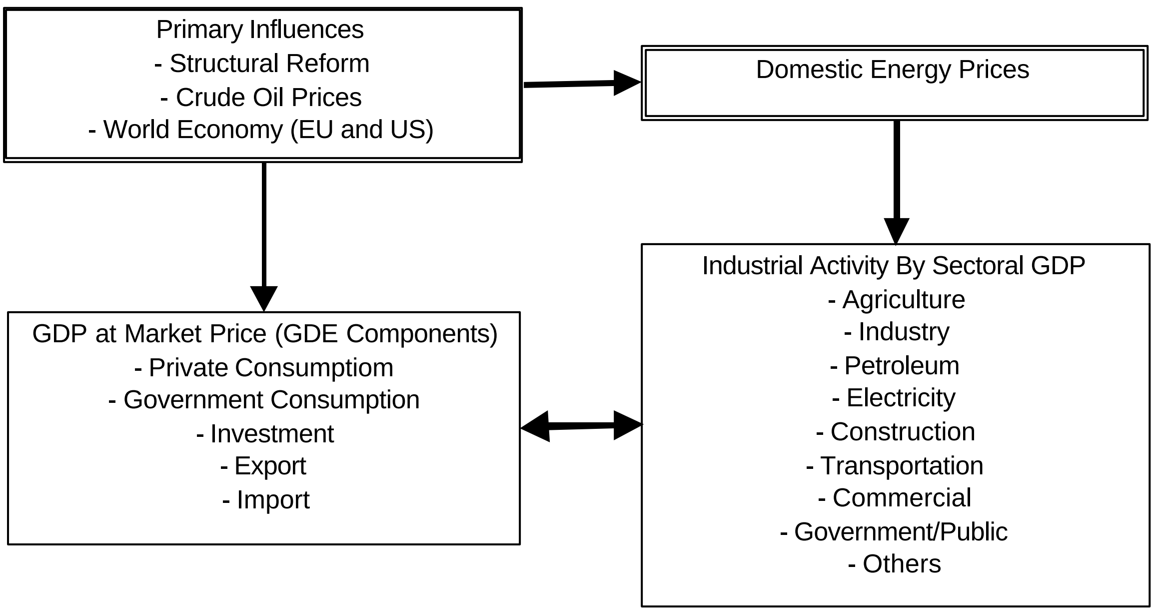
1 Concept

1.1 Basic Concept and the Model Basic Components

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 block diagram below shows the basic concept of the model. Here, the structural reform, crude oil price and world economy are the major determinant of domestic energy prices and the overall economic performance represented by GDP at market price. The industrial activities are represented by sectoral GDP. This sectoral GDP has the interrelationship with the overall GDP, while its connection to domestic energy prices are expected to be direct.

Basic Concept



The 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 such factors like structural reform and world economy will influence overall economy from various aspects, but they do not distinguish one specific sector, except the case of crude oil, which has direct link with petroleum sector. Here the influences from domestic parameters such as energy prices are indirect. On the other hand, the industrial activity is not a direct function of such major determinants. The relationship is indirect through the overall performance of GDP and is directly related with variables like energy prices.

In this concept, the role of GDP at market price is to determine its overall magnitude principally in relation to these major determinants. The role of sectoral GDP is to determine its sectoral structure in relation to such domestic factors as energy prices. In actual model, the sectoral share is redistributed to match the magnitude of total GDP at factor cost based on the total GDP at market price.

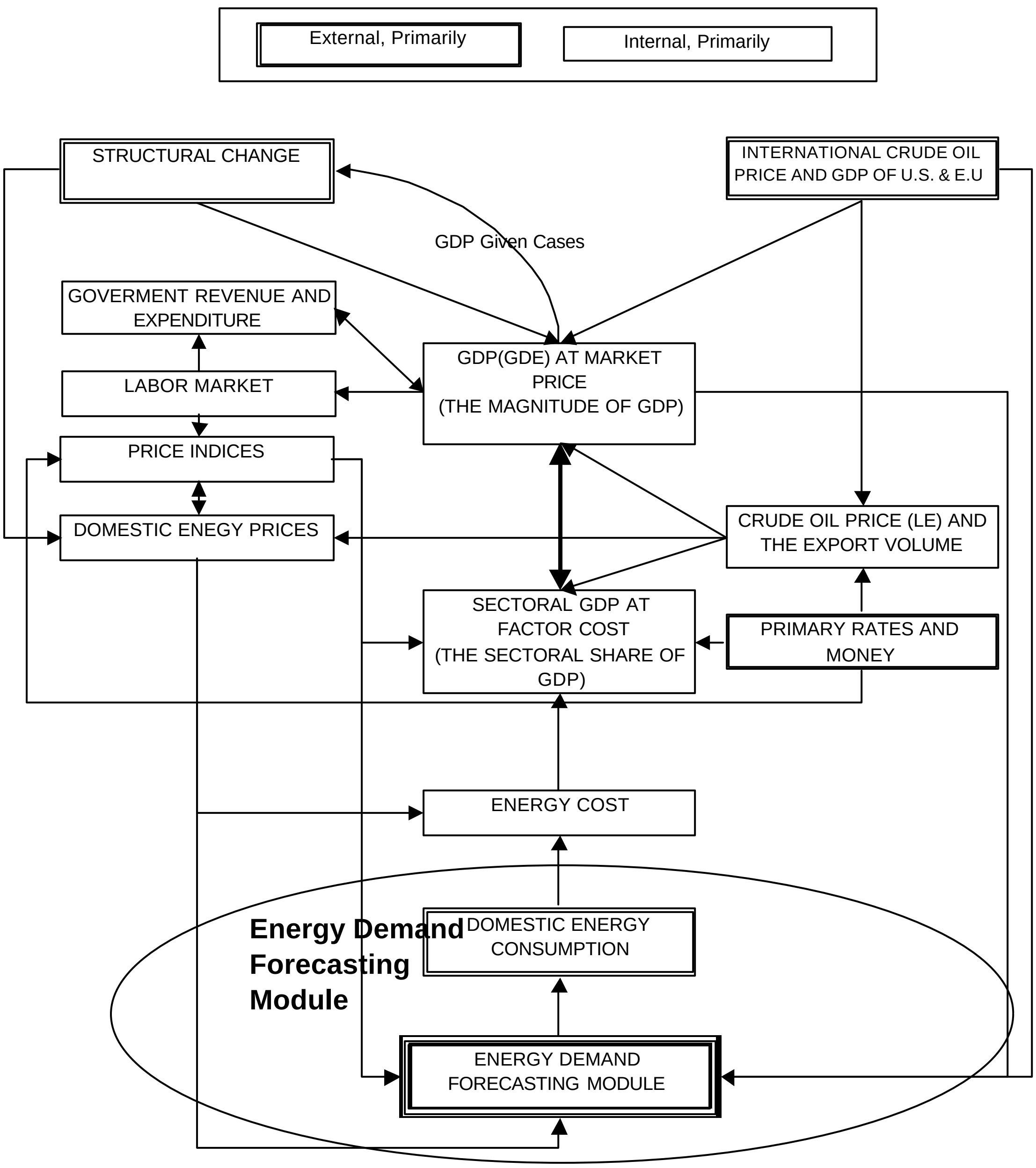
1.2 Model Components, the Flows, and the Link with Demand Module

Based on the above concept and the availability of macroeconomic data, the following 12 groups of variables are prepared.

(1) Structural reform
(2) International crude oil price and GDP of US & EU
(3) GDP at market price
(4) Sectoral GDP
(5) Government revenue and expenditure
(6) Labor market
(7) Price indices
(8) Domestic energy prices
(9) Primary rates and money
(10) Crude oil price in LE and the export volume
(11) Energy cost
(12) Energy consumption (Energy Demand Forecasting Module)

The flowchart of these groups are shown next. This flowchart provides a blueprint for the specification of the model. The specified relationship in arrows is the model default setting. Because of the nature of the transparency and adjustability of the model all relationships can be modified based on the necessity. For example, the default setting of the GDP is endogenous. However, if required to make it external, the user can modify the link, for example, to adjust the external variable of structural change so that it gives the predetermined value of GDP.

Model Flow



External, Primarily
Internal, Primarily
STRUCTURAL CHANGE
INTERNATIONAL CRUDE OIL PRICE AND GDP OF U.S. & E.U
GDP Given Cases
GOVERMENT REVENUE AND EXPENDITURE
LABOR MARKET
GDP(GDE) AT MARKET PRICE (THE MAGNITUDE OF GDP)
PRICE INDICES
DOMESTIC ENEGY PRICES
CRUDE OIL PRICE (LE) AND THE EXPORT VOLUME
SECTORAL GDP AT FACTOR COST (THE SECTORAL SHARE OF GDP)
PRIMARY RATES AND MONEY
ENERGY COST
Energy Demand Forecasting Module
DOMESTIC ENERGY CONSUMPTION
ENERGY DEMAND FORECASTING MODULE

2. Contents of each Group

(1) Structural Reform

Structural reform cannot be represented by single policy variable. Rather it represents an aggregate change caused by many policies for market reform to improve the economic performance. These policies are implemented since 1991 simultaneously and continuously. In this context, the most important characteristics of this factor are that it starts from 1991 and continuing. In this regard, the variable of structural reform can be defined as a qualitative variable to distinguish before 1991 and since 1991. In the model, the structural variable is defined to be one before 1991 and over 1.1 from 1991.

As a default, structural reform is an exogenous variable.

(2) International Crude Oil Price and GDP of US and EU

These are exogenous. Crude oil price is linked with export and petroleum sector GDP. GDP of US and EU are linked with export, because US and EU are Egypt's major export destinations. The daefault setting is 6% annual growth (average growth rate between 1990-2000).

(3) GDP at Market Price

As a default, GDP at market price is internalized as a function of the above variables. It is defined as a sum of private consumption, government consumption, investment, export, and import.

Private consumption is explained using its lagged variable, GDP minus tax revenue to represent the income level, and structural reform. The direct impact of structural reform is expected to be negative, because the structural reform is promoting investment, means decrease in consumption to increase the savings for investment. However, because of the total increase of GDP could cause net increase in consumption.

Government consumption is explained by its lagged variable, total tax revenue, and structural reform. The impact of structural reform is expected to be negative, because, it is promoting the shrink of public sector or privatization.

Investment is a function of the sum of sectoral GDP represent the economic performance of industrial actitivities, structural reform and interest rate. The impact of interest should be negative, because the smaller the borrowing rate increase the supply of money for investment. Also, the larger deposit rate will increase the saving to be used for investment.

Export is explained by the GDP of US and EU. Also, the export value of crude oil, exchange rate, and structural reform is related.

Import is explained by the GDP at factor cost to represent the industrial activity and exchange rate. The impact of exchange rate should be negative from the point of conventional trade theory.

(4) Sectoral GDP

Sectoral GDP is internalized. The eight sectors are agriculture, industry, petroleum, electricity, construction, transportation, commercial, government and others. The GDP at factor cost is the sum of these sectoral GDP.

Each sectoral GDP is explained by its lagged variable, sectoral GDP total and the related energy cost or revenue. The impact of energy cost is expected to be negative, however, for petroleum sector and electricity sector the related energy cost in other sector is their revenues; therefore the impacts should be positive.

(5) Government Revenue and Expenditure

The government revenue is explained by income level using GDP and wage. Also related is the income of EGPC surplus. The expenditure is explained by the total revenue, wage and unemployment. Because one of the most important role of the government to keep the employment level as high as possible.

(6) Labor Market

The variables of labor markets are population, labor force, unemployment rate and wage. Population is exogenous (2.1% growth as a default). Labor force is explained by population. Unemployment rate is explained by labor force to represent the labor supply pressure and GDP at factor cost to represent the labor demand pressure. Wage is explained by GDP per labor force to represent the labor productivity and the wholesale price index as a signal of labor demand for wage increase.

(7) Price Indices

Price indices include wholesale price index, consumer price index, and inflation rate. The wholesale price index is explained by wage to represent the labor cost, money supply and the exchange rate, which represent the cost of import goods and services. Consumer price index was explained by wage to represent the pressure of cost increase, money supply and the average of the prices of petroleum products to represent the influence of energy prices.

(8) Domestic Energy Prices

Domestic energy prices include electricity prices of industry, agriculture, commercial, residential and government and also include prices of petroleum products of gasoline, kerosene, diesel oil, diesel oil for transportation, LPG, natural gas, and coal.

The electricity prices are determined politically. However, in the long-run, the price is expected to follow the cost increase. Also, they are the subjects of structural reform. In this regard, the electricity price especially of industry is explained by its lagged variable, wholesale price index, and structural reform. The other electricity prices are explained by the price of industry sector.

The petroleum products prices are determined politically. However, in the long-run the price is expected to follow the shadow market price—that is international price. Also like other industry, the petroleum industry is under the pressure of cost increase and structural reform. In this regard, the gasoline price, as a representative of petroleum products, is explained by its lagged variable, crude oil price in LE, wholesale price index, and structural reform. Other prices are explained by this gasoline price.

(9) Primary Rates and Money

Primary rates include central bank rate, rending rate, deposit rate, exchange rate, and money supply. Central bank rate and money supply are exogenous as policy instruments. As a default, central bank rate is assumed to be a function of last year's rate. Money supply is assumed to have the same growth rate of GDP. Rending rate and deposit rate are explained by central bank rate, money supply and inflation. Exchange rate is explained, considering the purchasing power parity, by the real exchange rate or the ratio of the GDP deflator of US and Egypt.

(10) Crude Oil Price in LE and the Export Volume

Crude oil price in LE and the export volume are important to translate the $US value of crude oil export into the value of Egyptian domestic value. Crude oil price in LE is a simple calculation of crude oil price in $US multiplied by exchange rate (LE/$US). The export volume is an exogenous variable. As a default, it is defined as the continuation of the latest value.

(11) Energy Cost

Energy cost variables are the major determinants of sectoral GDP as the cost factor. The electricity costs are calculated using their prices and the consumption estimates given by demand-forecasting module for the sectors of industry, agriculture, commercial, residential and government. The petroleum products costs are calculated using their prices and the consumption estimates given by the demand-forecasting module for the sectors of agriculture, industry, residential/commercial, and transportation. As a default the prices are represented by diesel price as an average of petroleum products pricres.

(12) Energy Consumption

Energy consumption by sector is exogenous variable from the point of Macro-economic module. The estimates are given from the demand-forecasting module.

3. List of Variables

No.	Variable	Unit	Code	Original Source
	Crude Oil Price and World Economy			
1	Crude Oil (CIF Japan $US/bbl)	$/Bbl	PCR	Datasheet
2	GDP, US	1995, Billion $US	USGDP	Datasheet
3	US GDP DEFLATOR	1996=100	USDEF	Datasheet
4	GDP, OECD EUROPE	1995, Billion $US	EUGDP	Datasheet
	Structural Reform			
5	Structural Reform	1990=1	SR	Datasheet
	GDP at Market Price			
6	Total GDP at Market Price	Million LE, 1996/97 Constant	GDP	Model Defined
7	Private Consumption	Million LE, 1996/97 Constant	PC	Datasheet
8	Government Consumption	Million LE, 1996/97 Constant	GC	Datasheet
9	Investment	Million LE, 1996/97 Constant	I	Datasheet
10	Exports	Million LE, 1996/97 Constant	X	Datasheet
11	Imports	Million LE, 1996/97 Constant	M	Datasheet
12	Share of GDP Components	Ratio	GDP.S	Model Defined
13	Share of Private Consumption	Ratio	PC.S	Model Defined
14	Share of Government Consumption	Ratio	GC.S	Model Defined
15	Share of Investment	Ratio	I.S	Model Defined
16	Share of Export	Ratio	X.S	Model Defined
17	Share of Import	Ratio	M.S	Model Defined
18	GDP Deflator	1996=100	GDPDEF	Datasheet
19	GDP Nominal	Million L.E.	GDP.N	Model Defined
20	GDP per Capita, Nominal	L.E	GDPPC.N	Model Defined
21	GDP per Capita, Real	LE, 1996/97 Constant	GDPPC	Model Defined
22	GDP in $US, Real	Million $US	GDP.D	Model Defined
23	GDP, Purchasing Power Adjusted, $US Real	Million $US	GDP.P	Model Defined
	Sectoral Value Added			
24	Total GDP at Factor Cost	Million LE, 1996/97 Constant	GDP.F	Model Defined
25	Agriculture, Factor Cost	Million LE, 1996/97 Constant	GDPAG	Datasheet
26	Industry, Factor Cost	Million LE, 1996/97 Constant	GDPIN	Datasheet
27	Petroleum, Factor Cost	Million LE, 1996/97 Constant	GDPPT	Datasheet
28	Electricity, Factor Cost	Million LE, 1996/97 Constant	GDPEL	Datasheet
29	Construction, Factor Cost	Million LE, 1996/97 Constant	GDPCN	Datasheet
30	Transportation, Factor Cost	Million LE, 1996/97 Constant	GDPTR	Datasheet
31	Commercial, Factor Cost	Million LE, 1996/97 Constant	GDPCM	Datasheet
32	Government / public, Factor Cost	Million LE, 1996/97 Constant	GDPGV	Datasheet
33	Others, Factor Cost	Million LE, 1996/97 Constant	GDPOT	Datasheet

34	Share of Agriculture, Factor Cost	Ratio	AGR.S	Model Defined
35	Share of Industry, Factor Cost	Ratio	IND.S	Model Defined
36	Share of Petroleum, Factor Cost	Ratio	PET.S	Model Defined
37	Share of Electricity, Factor Cost	Ratio	ELE.S	Model Defined
38	Share of Construction, Factor Cost	Ratio	CON.S	Model Defined
39	Share of Transportation, Factor Cost	Ratio	TRA.S	Model Defined
40	Share of Commercial, Factor Cost	Ratio	COM.S	Model Defined
41	Share of Government / public, Factor Cost	Ratio	GOV.S	Model Defined
42	Share of Others, Factor Cost	Ratio	OTH.S	Model Defined
43	Total GDP at Factor Cost Calculated	Million LE, 1996/97 Constant	GDPF	Model Defined
44	Total GDP AT Factor Cost Share, Calculated	Ratio	GDPF.S	Model Defined
45	Total GDP at Factor Cost, Adjusted	Million LE, 1996/97 Constant	GDPF.A	Model Defined
46	Agriculture Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPAG.A	Model Defined
47	Industry Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPIN.A	Model Defined
48	Petroleum Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPPT.A	Model Defined
49	Electricity Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPEL.A	Model Defined
50	Construction Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPCN.A	Model Defined
51	Transportation Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPTR.A	Model Defined
52	Commercial Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPCM.A	Model Defined
53	Government Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPGV.A	Model Defined
54	Other Sector, Adjusted GDP	Million LE, 1996/97 Constant	GDPOT.A	Model Defined
	Price Indices			
55	WPI	1996=100	WPI	Datasheet
56	CPI, Urban	1996/97=100	CPIU	Datasheet
57	Inflation	%	INFL	Model Defined
	Governmental Revenues and Expenditures			
58	Total Revenue	Million L.E.	RVTTL	Datasheet
59	Tax Revenue	Million L.E.	RVTX	Datasheet
60	Oil surplus " EGPC", Revenue	Million L.E.	RVEG	Datasheet
61	Suez canal, Revenue	Million L.E.	RVSZ	Datasheet
62	Others (Total Rev.-Tax Rev. - Oil Surplus –Suez)	Million L.E.	RVOT	Datasheet
63	Current&Capital Expenditure	Million L.E.	EPTTL	Datasheet
64	Capital expenditure	Million L.E.	EPCP	Datasheet
65	Wages, Current expenditure	Million L.E.	EPWG	Datasheet
66	Others (Total Ex. - Cap. Ex. - Wage Ex.)	Million L.E.	EPOT	Datasheet
67	Overall Balance	Million L.E.	BUDBAL	Datasheet
	Primary Rates and Money			
68	Central Bank Rate	%	IR	Datasheet
69	Lending Rate	%	LR	Datasheet
70	Deposit Rate	%	DR	Datasheet
71	Exchange rate	L.E./Us$	EXR	Datasheet

72	Real Exchange Rate	1996=100	EXR.R	Model Defined
73	Purchasing Power Adjusted	L.E./Us$	EXR.P	Model Defined
74	Money (M2)	Billion L.E.	MONEY	Datasheet
	Price of Crude Oil in LE			
75	Price of Crude Oil in LE	LE/bbl	PCRE	Model Defined
	Labor Market			
76	Population	1,000 Persons	POP	Datasheet
77	Total Labor Force	1,000 Persons	LF	Datasheet
78	Rate of Unemployment	%	UR	Datasheet
79	Average Wage per Worker	L.E./Person	WG	Datasheet
	Energy Prices			
80	Industry	PT/Kwh	PELIN	Datasheet
81	Agriculture	PT/Kwh	PELAG	Datasheet
82	Commercial	PT/Kwh	PELCM	Datasheet
83	Residential	PT/Kwh	PELRE	Datasheet
84	Government/Public Utility	PT/Kwh	PELGV	Datasheet
85	Industry	LE/Toe	PELINU	Model Defined
86	Agriculture	LE/Toe	PELAGU	Model Defined
87	Commercial	LE/Toe	PELCMU	Model Defined
88	Residential	LE/Toe	PELREU	Model Defined
89	Government/Public Utility	LE/Toe	PELGVU	Model Defined
90	Gasoline	LE/Toe	PGASO	Datasheet
91	Kerosene	LE/Toe	PKERO	Datasheet
92	Diesel/Gas Oil for P/P (Boiler)	LE/Toe	PDO	Datasheet
93	Diesel/Gas Oil For Transportation	LE/Toe	PDOTR	Datasheet
94	Fuel Oil	LE/Toe	PFO	Datasheet
95	LPG	LE/Toe	PLPG	Datasheet
96	Natural Gas	LE/Toe	PNG	Datasheet
97	Average	LE/Toe	PAVE	Datasheet
98	Coal (CIF, EU)	US$/Ton	PCC	Datasheet
	Energy Cost			
99	Petroleum Product Consumption Total	Ktoe	TTPT	Datasheet
100	Industry Electricity Cost	Million L.E	INELC	Model Defined
101	Agriculture Electricity Cost	Million L.E	AGELC	Model Defined
102	Commercial Electricity Cost	Million L.E	CMELC	Model Defined
103	Residential Electricity Cost	Million L.E	REELC	Model Defined
104	Government/Public Utility Electricity Cost	Million L.E	GVELC	Model Defined
105	Total Electricity Cost	Million L.E	FNELC	Model Defined
106	Agriculture Energy Cost	Million L.E	AGPTC	Model Defined
107	Industry Energy Cost	Million L.E	INPTC	Model Defined

108	Commercial & Residential Energy Cost	Million L.E	RCPTC	Model Defined
109	Transportation Energy Cost	Million L.E	TRPTC	Model Defined
110	Total Petroleum Fuel Cost	Million L.E	TTPTC	Model Defined
111	Total Energy Cost	Million L.E	TTEC	Model Defined
112	Share of Total Energy Cost	Ratio	TTECS	Model Defined
	From Demand Forecasting Module			
113	Export	Ktoe	EXCR	Datasheet
114	Petroleum Product Total	Ktoe	AGPT	Datasheet
115	Petroleum Products Total	Ktoe	INPT	Datasheet
116	Petroleum Products Total	Ktoe	RCPT	Datasheet
117	Petroleum Products Total	Ktoe	TRPT	Datasheet
118	Industry	GWh	INEL	Datasheet
119	Agriculture	GWh	AGEL	Datasheet
120	Commercial	GWh	CMEL	Datasheet
121	Residential	GWh	REEL	Datasheet
122	Government/Public Utility	GWh	GVEL	Datasheet

4. Model Specifications

The followings show the current model specifications.

(1) Structural Reform

Case	Y	Type	X1
SR1	SR		
SR2	SR	$SR=	ZEROSEARCH((1/(PC+GC+I+X-M)-1/GDP)*2000,SR,-1,1,1.2)

Structural Reform: SR

Currently there are two alternatives.

- Case SR1: Use SR in datasheet directly: Use the default below model No.SR1 to set SR directly as a predetermined variable in datasheet.
- Case SR2: Internalize SR so that it gives the predetermined GDP: Use the below model No.SR2. The function ZEROSERACH is a function to adjust itself (SR) to make the first argument (1/(PC+GC+I+X-M)-1/GDP) to be zero. Namely, this function searches SR for each year to equalize the given GDP and the calculated value of PC + GC + I + X - M.

(2) International Crude Oil Price and GDP of US and EU

Y	Type	X1
PCR	=	LAG1.PCR*1.06
USGDP	=	LAG1.USGDP*1.04
USDEF	=	LAG1.USDEF*1.015
EUGDP	=	LAG1.EUGDP*1.02

International Price of Crude Oil: PCR

The default assumption is 6% growth rate as shown below. This is the average of annual growth rate between 1990 and 2000.

GDP of US: USGDP

The default assumption is 4% growth rate as shown below. This is the growth rate of latest years.

GDP deflator of US: USDEF

The default assumption is 1.5% growth rate as shown below. This is the growth rate of latest years.

GDP of EU: EUGDP

The default assumption is 2% growth rate as shown below. This is the growth rate of latest years.

(3) GDP at Market Price

- Real GDP at market Price

Case	Y	Type	X1	X2	X3	X4
GDP1	GDP	=	PC+GC+I+X-M			
GDP2	GDP	=	LAG1.GDP*GDP.F/LAG1.GDP.F			
	PC	$CA	LAG1.PC	GDP-RVTX/GDPDEF	SR	
	GC	$CA	LAG1.GC	LAG1.RVTTL	SR	
	I	$CA	LAG1.GDPF	SR*LAG1.GDPF	SR	LR-DR
	X	$CA	USGDP/3+EUGDP	EXCR*PCRE/GDPDEF	EXR.P+Lag1.EXR.P	SR/LAG1.SR
	M	$CA	GDPF	EXR		

Gross Domestic Product at market price: GDP

Currently there are two alternatives.

- Case GDP1: Internalize GDP based on the GDP identity.
- Case GDP2: Internalize GDP so that the growth rate is the same as GDP at factor cost. This case is used when the GDP at factor cost or the industrial value added is predetermined.

Personal Consumption at market price: PC

PC is explained by the past consumption level, income level, and structural reform. Lag1.PC is previous year's PC. RVTX is national tax revenue in nominal price and GDPDEF is GDP deflator. Therefore, GDP-RVTX/GDPDEF represents national income after tax. SR is structural reform.

Government Consumption at market price: GC

GC is explained by the past consumption level, total national revenue of previous year, and structural reform. Lag1.GC is previous year's GC. Lag1.RVTTL is previous year's total national revenue.

Investment: I

I is explained primarily by industrial activity, using industrial value added total (GDP at factor cost) of both previous year and current year, rending rate LR, deposit rate DR and structural reform SR.

Export: X

X is explained by economic activity of US (USGDP) and OECD Europe (EUGDP), real exchange rate EXR.R, crude oil export revenue EXCR*PCRE/GDPDEF, exchange rate EXR, and structural reform growth SR/LAG1.SR.

Import: M

M is explained by industrial activity level GDPF and exchange rate EXR.

- Component Share of GDP at market Price

Y	Type	X1
GDP.S	=	(PC+GC+I+X-M)/GDP
PC.S	=	PC/GDP
GC.S	=	GC/GDP
I.S	=	I/GDP
X.S	=	X/GDP
M.S	=	M/GDP

Share of GDP: GDP.S

This is the share of calculated GDP in given GDP. If GDP is given externally, the calculated GDP or PC+GC+I+X-M could be different from the given GDP. If GDP is defined as PC+GC+I+X-M, then this value should be one.

Share of Private Consumption: PC.S

This is the share ratio of private consumption (PC) in GDP.

Share of Government Consumption: GC.S

This is the share ratio of government consumption (GC) in GDP.

Share of Investment: I.S

This is the share ratio of investment (I) in GDP.

Share of Export: X.S

This is the share ratio of export (X) in GDP.

Share of Import: M.S

This is the share ratio of import (M) in GDP.

- GDP deflator and the related

Y	Type	X1	X2
GDPDEF	$CA	MONEY	WPI
GDP.N	=	GDP*GDPDEF/100	
GDPPC.N	=	GDP.N/POP*1000	
GDPPC	=	GDP/POP*1000	
GDP.D	=	GDP/EXR	
GDP.P	=	GDP/EXR.P	

GDP deflator: GDPDEF

GDP deflator is explained by money supply (MONEY) and wholesale price index (WPI).

Nominal GDP: GDP.N

Nominal GDP is defined by multiplying GDP and the deflator (GDPDEF).

Nominal GDP per capita: GDPPC.N

Nominal GDP per capita is defined by nominal GDP (GDP.N) divided by population (POP).

Real GDP per capita: GDPPC

Real GDP per capita is defined by real GDP (GDP) divided by population (POP).

Real GDP in $US: GDP.D

Real GDP in $US is defined by real GDP (GDP) divided by exchange rate (EXR).

Real GDP in $US, purchasing power adjusted: GDP.P

Purchasing power adjusted Real GDP in $US is defined by real GDP (GDP) divided by purchasing power adjusted exchange rate (EXR.P).

(4) Sectoral GDP (GDP at factor cost)

- Real GDP at factor cost by sector

Y	Type	X1	X2	X3	X4
GDP.F	=	GDPAG+GDPIN+GDPPT+GDPEL+GDPCN+GDPTR+GDPCM+GDPGV+GDPOT			
GDPAG	$CA	LAG1.GDPAG	GDPF	(AGELC+AGPTC)/(LAG1.AGELC+LAG1.AGPTC)	
GDPIN	$CA	LAG1.GDPIN	GDPF	(INELC+INPTC)/(LAG1.INELC+LAG1.INPTC)	
GDPPT	$CA	LAG1.GDPPT	TTPTC	LAG1.PCRE/LAG1.CPIU+LAG2.PCRE/LAG2.CPIU+LAG3.PCRE/LAG3.CPIU	
GDPEL	$CA	LAG1.GDPEL	FNELC/LAG1.FNELC	INPTC/LAG1.INPTC	DUM.1986
GDPCN	$CA	LAG1.GDPCN	GDPF	TTEC/LAG1.TTEC	
GDPTR	$CA	LAG1.GDPTR	GDPF	TRPTC/LAG1.TRPTC	
GDPCM	$CA	LAG1.GDPCM	GDPF	(CMELC+RCPTC)/(LAG1.CMELC+LAG1.RCPTC)	
GDPGV	$CA	LAG1.GDPGV	GDPF	TTEC/LAG1.TTEC	
GDPOT	$CA	LAG1.GDPOT	GDPF	LAG1.TTEC/LAG2.TTEC	

Sectoral GDP Total: GDP.F

Sectoral GDP total is defined as the sum of the value added of sectors: agriculture (GDPAG), industry (GDPIN), petroleum (GDPPT), electricity (GDPEL), construction (GDPCN), transportation (GDPTR), commercial (GDPCM), government (GDPGV), and the others (GDPOT).

Sectoral GDP, Agriculture: GDPAG

Agriculture sector value added is explained by its past (LAG1.GDPAG), total GDP adjusted sectoral GDP (GDPF), and energy cost of electricity (AGELC) and petroleum products (AGPTC).

Sectoral GDP, Industry: GDPIN

Industry sector value added is explained by its past (LAG1.GDPIN), total GDP adjusted sectoral GDP (GDPF), and energy cost of electricity (INELC) and petroleum products (INPTC).

Sectoral GDP, Petroleum: GDPPT

Petroleum sector value added is explained by its past (LAG1.GDPPT), petroleum product sales revenue (total petroleum cost TTPTC), and average crude oil price (crude oil price in LE PCRE divide by consumer price index CPIU) of past three years.

Sectoral GDP, Electricity: GDPEL

Electricity sector value added is explained by its past (LAG1.GDPEL), fuel cost (represented by industry INPTC), and electricity sales revenue (total electricity cost FNELC).

Sectoral GDP, Construction: GDPCN

Construction sector value added is explained by its past (LAG1.GDPCN), total GDP adjusted sectoral GDP (GDPF), and energy cost (represented by total energy cost TTEC).

Sectoral GDP, Transportation: GDPTR

Transportation sector value added is explained by its past (LAG1.GDPTR), total GDP adjusted sectoral GDP (GDPF), and petroleum products cost (TRPTC).

Sectoral GDP, Government: GDPGV

Government/public sector value added is explained by its past (LAG1.GDPGV), total GDP adjusted sectoral GDP (GDPF), and energy cost (represented by total electricity cost TTEC).

Sectoral GDP, Others: GDPOT

Government/public sector value added is explained by its past (LAG1.GDPOT), total GDP adjusted sectoral GDP (GDPF), and energy cost (represented by total electricity cost TTEC).

- Sectoral share

Y	Type	X1
AGR.S	=	GDPAG/GDP.F
IND.S	=	GDPIN/GDP.F
PET.S	=	GDPPT/GDP.F
ELE.S	=	GDPEL/GDP.F
CON.S	=	GDPCN/GDP.F
TRA.S	=	GDPTR/GDP.F
COM.S	=	GDPCM/GDP.F
GOV.S	=	GDPGV/GDP.F
OTH.S	=	GDPOT/GDP.F

Share of agriculture sector: AGR.S
This is the share ratio of agriculture sector value added (GDPAG) in total (GDP.F).

Share of industry sector: IND.S
This is the share ratio of industry sector value added (GDPIN) in total (GDP.F).

Share of petroleum sector: PET.S
This is the share ratio of petroleum sector value added (GDPPT) in total (GDP.F).

Share of electricity sector: ELE.S
This is the share ratio of electricity sector value added (GDPEL) in total (GDP.F).

Share of construction sector: CON.S
This is the share ratio of construction sector value added (GDPCN) in total (GDP.F).

Share of transportation sector: TRA.S
This is the share ratio of transportation sector value added (GDPTR) in total (GDP.F).

Share of commercial sector: COM.S
This is the share ratio of commercial sector value added (GDPCM) in total (GDP.F).

Share of government/public sector: GOV.S
This is the share ratio of government/public sector value added (GDPGV) in total (GDP.F).

Share of other sector: OTH.S
This is the share ratio of other sector value added (GDPOT) in total (GDP.F).

- GDP adjusted sectoral GDP total and the share

Case	Y	Type	X1
GDPF1	GDPF	=	LAG1.GDPF*(GDP/LAG1.GDP)
GDPF2	GDPF	=	GDP.F
	GDPF.S	=	GDPF/GDP.F

GDP adjusted sectoral GDP total: GDPF

- Case GDPF1: Adjust GDPF so that the growth rate becomes the same as real GDP at market price. This is a default setting.
- Case GDPF2: Sectoral GDP will not be adjusted, but be defined to be the same as GDP.F. This case will be used when the sectoral GDP or its components are predetermined or given; therefore GDP at market price must be determined based on the give value of sectoral GDP. This case corresponds to "Case GDP2" of GDP model specification.

Ratio of adjusted and non adjusted sectoral GDP: GDPF.S
This is the ratio of GDP adjusted sectoral GDP (GDPF) over non-adjusted sectoral GDP total (GDP.F).

- Sectoral GDP, Adjusted

Y	Type	X1
GDPF.A	=	GDPAG.A+GDPIN.A+GDPPT.A+GDPEL.A+GDPCN.A+GDPTR.A+GDPCM.A+GDPGV.A+GDPOT.A
GDPAG.A	=	GDPAG*GDPF.S
GDPIN.A	=	GDPIN*GDPF.S
GDPPT.A	=	GDPPT*GDPF.S
GDPEL.A	=	GDPEL*GDPF.S
GDPCN.A	=	GDPCN*GDPF.S
GDPTR.A	=	GDPTR*GDPF.S
GDPCM.A	=	GDPCM*GDPF.S
GDPGV.A	=	GDPGV*GDPF.S
GDPOT.A	=	GDPOT*GDPF.S

Sectoral GDP Total, Adjusted: GDPF.A
Adjusted sectoral GDP total is defined as the sum of the adjusted value added of sectors: agriculture (GDPAG.A), industry (GDPIN.A), petroleum (GDPPT.A), electricity (GDPEL.A), construction (GDPCN.A), transportation (GDPTR.A), commercial (GDPCM.A), government (GDPGV.A), and the others (GDPOT.A). GDPF.A should be equal to GDPF (the GDP adjusted sectoral GDP).

Adjusted Sectoral GDP, Agriculture: GDPAG.A
Agriculture sector GDP (GDPAG) is adjusted in proportion to GDPF.S (the ratio of adjusted sector GDP over non-adjusted sectoral GDP).

Adjusted Sectoral GDP, Industry: GDPIN.A
Industry sector GDP (GDPIN) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Petroleum: GDPPT.A
Petroleum sector GDP (GDPPT) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Electricity: GDPEL.A
Electricity sector GDP (GDPEL) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Construction: GDPCN.A
Construction sector GDP (GDPCN) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Transportation: GDPTR.A
Transportation sector GDP (GDPTR) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Government: GDPGV.A
Government/public sector GDP (GDPGV) is adjusted in proportion to GDPF.S.

Adjusted Sectoral GDP, Others: GDPOT.A
Others sector GDP (GDPOT) is adjusted in proportion to GDPF.S.

(4) Price Indices

Y	Type	X1	X2	X3
WPI	$CA	LAG1.WG	MONEY	LAG1.EXR
CPIU	$CA	WG	MONEY	PELIN+PELAG+PELCM+PELRE+PELGV
INFL	=	(CPIU/LAG1.CPIU-1)*100		

Wholesale price index: WPI
Wholesale price index is explained by wage (WG) to represent cost increase, money supply (MONEY) to represent the circulated money volume and exchange rate (EXR) to represent the price level of imported goods and services.

Consumer price index: CPIU
Consumer price index is explained by wage (WG) to represent cost increase, money supply (MONEY) to represent the circulated money volume and energy (petroleum products) prices to represent the impact of energy price changes.

Inflation: INFL

Inflation is defined as a growth rate of consumer price index (CPIU) in percent.

(5) Government Revenue and Expenditure (Nominal)

Y	Type	X1	X2	X3
RVTTL	=	RVTX+RVEG+RVSZ+RVOT		
RVTX	$CA	GDP.N	WG-LAG1.WG	
RVEG	$CA	PCRE*EXCR	TTPTC	
RVSZ	$TG			
RVOT	$CA	LAG1.RVOT		
EPTTL	=	RVTTL-BUDBAL		
EPCP	=	RVTTL-EPWG-EPOT		
EPWG	$CA	LAG1.WG	RVTTL	UR
EPOT	$CA	RVOT	UR	
BUDBAL	$CA	UR/LAG1.UR	LAG1.UR/LAG2.UR	GDPDEF

Government total revenue: RVTTL

Government total revenue is defined as a sum of tax revenue (RVTX), EGPC surplus (RVEG), revenue from Suez Canal (RVSZ), and others (RVOT).

Tax revenue: RVTX

Tax revenue is explained by nominal GDP and increase in wage (WG).

EGPC surplus: RVEG

EGPC surplus is explained by export revenue (PCRE*EXCR) and domestic sales of petroleum products represented by the petroleum cost of other sectors (TTPTC).

Suez canal: RVSZ

Suez canal revenue is explained by the growth trend projection.

Other revenue: RVOT

Other revenue is explained by itself—its previous year (LAG1.RVOT).

Government expenditure total: EPTTL

Government expenditure total is defined as total revenue (RVTTL) minus budget balance (BUDBAL).

Capital expenditure: EPCP

Capital expenditure total is defined as total revenue (RVTTL) minus wage expenditure (EPWG) minus other expenditure (EPOT).

Wage expenditure: EPWG

Wage expenditure is explained by wage level of last year, total revenue, and unemployment rate.

Other expenditure: EPOT

Other expenditure is explained by other revenue and unemployment rate.

Budget balance: BUDBAL

Budget balance is explained by the growth of unemployment rate of the past two successive years, and GDP deflator to represent the general price level.

(9) Primary Rates and Money

Y	Type	X1	X2	X3
IR	=	LAG1.IR		
LR	$CA	IR	MONEY-LAG1.MONEY	INFL
DR	$CA	IR	MONEY-LAG1.MONEY	INFL
EXR	$CA	1/EXR.R		
EXR.R	=	GDPDEF/USDEF*100		
EXR.P	=	EXR*EXR.R		
MONEY	=	lag1.Money*GDP/Lag1.GDP		

Official discount rate (central bank rate): IR

IR is defined as the same of previous year.

Lending rate: LR

Lending rate is explained by central bank rate (IR), money supply (MONEY), and inflation (INFL).

Deposit rate: DR

Deposit rate is explained by central bank rate (IR), money supply (MONEY), and inflation (INFL).

Exchange rate: EXR

Exchange rate is explained by real exchange rate (EXR.R).

Real exchange rate: EXR.R

Real exchange rate is an indicator of the difference of purchasing power, which is defined by the ratio of GDP deflator of Egypt and that of the US, considering that the exchange rate of Egypt is pegged on $US.

Money supply: MONEY
Money supply is assumed to grow at the same rate of GDP.

(10) Crude Oil Price in LE

Y	Type	X1
PCRE	=	PCR*EXR

Crude oil price in LE: PCRE
Crude oil price in LE is defined by crude oil price in $US (PCR) and exchange rate (EXR).

(6) Labor Market

Y	Type	X1	X2
POP	=	LAG1.POP*1.021	
LF	$CA $DL	POP	
UR	$CA $DL	GDPF	LF
WG	$CA	WPI	GDPF/LF

Population: POP
Population is assumed to grow at the rate of 2.1%

Labor force: LF
Labor force is explained by population (POP).

Unemployment rate: UR
Unemployment rate is explained by demand side pressure represented by sectoral GDP total (GDPF) and supply side pressure represented by labor force (LF).

Wage: WG
Wage is explained by worker's demand pressure represented by general living cost or wholesale price index (WPI) and labor productivity represented by sectoral GDP per labor (GDPF/LF).

(8) Domestic Energy Prices

- Electricity Prices

Y	Type	X1	X2	X3
PELIN	$CA $DL	LAG1.PELIN	SR/LAG1.SR	LAG1.WPI
PELAG	=	LAG1.PELAG*PELIN/LAG1.PELIN		
PELCM	=	LAG1.PELCM*PELIN/LAG1.PELIN		
PELRE	=	LAG1.PELRE*PELIN/LAG1.PELIN		
PELGV	=	LAG1.PELGV*PELIN/LAG1.PELIN		
PELINU	=	LAG1.PELIN*0.086		
PELAGU	=	LAG1.PELIN*0.086		
PELCMU	=	LAG1.PELIN*0.086		
PELREU	=	LAG1.PELIN*0.086		
PELGVU	=	LAG1.PELIN*0.086		

Industry electricity price: PELIN

Industry electricity price is explained by its previous year's value, structural change (SR) and wholesale price index (WPI)

Agriculture electricity price: PELAG

Agriculture electricity price is assumed to grow at the same rate of industry electricity price (PELIN).

Commercial electricity price: PELCM

Commercial electricity price is assumed to grow at the same rate of industry electricity price (PELIN).

Residential electricity price: PELRE

Residential electricity price is assumed to grow at the same rate of industry electricity price (PELIN).

Government electricity price: PELGV

Government electricity price is assumed to grow at the same rate of industry electricity price (PELIN).

Industry unit electricity price (LE/toe): PELINU

Industry electricity price is converted from the unit PT/GWh to LE/toe using conversion factor 0.086.

Agriculture unit electricity price (LE/toe): PELAG

Agriculture electricity price is converted from the unit PT/GWh to LE/toe using conversion factor 0.086.

Commercial unit electricity price (LE/toe): PELCM
Commercial electricity price is converted from the unit PT/GWh to LE/toe using conversion factor 0.086.

Residential unit electricity price (LE/toe): PELRE
Residential electricity price is converted from the unit PT/GWh to LE/toe using conversion factor 0.086.

Government unit electricity price (LE/toe): PELGV
Government electricity price is converted from the unit PT/GWh to LE/toe using conversion factor 0.086.

- Petroleum Products and Coal Prices

Y	Type	X1	X2	X3	X4
PGASO	$CA $DL	LAG1.PGASO	LAG1.PCRE	SR/LAG1.SR	LAG1.WPI
PKERO	=	LAG1.PKERO*PGASO/LAG1.PGASO			
PDO	=	LAG1.PDO*PGASO/LAG1.PGASO			
PDOTR	=	LAG1.PDOTR*PGASO/LAG1.PGASO			
PFO	=	LAG1.PFO*PGASO/LAG1.PGASO			
PLPG	=	LAG1.PLPG*PGASO/LAG1.PGASO			
PNG	=	LAG1.PNG*PGASO/LAG1.PGASO			
PAVE	=	(PGASO+PKERO+PDO+PDOTR+PFO+PLPG+PNG)/7			
PCC	$CA $DL	PCR			

Gasoline price: PGASO
Gasoline price is explained by its previous year's value, crude oil price in LE, structural change (SR) and wholesale price index (WPI).

Kerosene price: PKERO
Kerosene price is assumed to grow at the same rate of gasoline price (PGASO).

Diesel price: PDO
Diesel price is assumed to grow at the same rate of gasoline price (PGASO).

Transportation diesel price: PELRE
Transportation diesel price is assumed to grow at the same rate of gasoline price (PGASO).

Fuel oil price: PFO

Fuel oil price is assumed to grow at the same rate of gasoline price (PGASO).

LPG price: PLPG
LPG price is assumed to grow at the same rate of gasoline price (PGASO).

Natural gas price: PNG
Natural gas price is assumed to grow at the same rate of gasoline price (PGASO).

Average price: PAVE
Average price is the average of the above 7 petroleum products prices.

Coking coal price: PCC
Coking coal price is explained by crude oil price.

(11) Energy Cost

Y	Type	X1
TTPT	=	AGPT+INPT+RCPT+TRPT
INELC	=	PELIN*INEL/WPI/10
AGELC	=	PELAG*AGEL/WPI/10
CMELC	=	PELCM*CMEL/WPI/10
REELC	=	PELRE*REEL/WPI/10
GVELC	=	PELGV*GVEL/WPI/10
FNELC	=	INELC+AGELC+CMELC+REELC+GVELC
AGPTC	=	(AGDO*PDO+AGKE*PKERO)/WPI/1000
INPTC	=	(INNP*PKERO+INDO*PDO+INFO*PFO+INLP*PLPG+INKE*PKERO)/WPI/1000
RCPTC	=	(RCLP*PLPG+RCKE*PKERO+RCDO*PDO)/WPI/1000
TRPTC	=	(TRGS*PGASO+TRDO*PDO+TRJT*PKERO+TRFO*PFO)/WPI/1000
TTPTC	=	AGPTC+INPTC+RCPTC+TRPTC
TTEC	=	FNELC+TTPTC
TTECS	=	TTEC/GDPF

- Total petroleum consumption

Total petroleum consumption: TTPT
Total petroleum consumption is defined by the sum of agriculture petroleum consumption (AGPT), industry petroleum consumption (INPT), residential/commercial petroleum consumption (RCPT), and transportation petroleum consumption (TRPT). These consumptions are provided by demand forecasting module.

- Electricity cost

Industry electricity cost: INELC

Industry electricity cost is calculated by the price (PELIN), consumption (INEL), and wholesale price index.

Agriculture electricity cost: AGELC

Agriculture electricity cost is calculated by the price (PELAG), consumption (AGEL), and wholesale price index.

Commercial electricity cost: CMELC

Commercial electricity cost is calculated by the price (PELCM), consumption (CMEL), and wholesale price index.

Residential electricity cost: REELC

Commercial electricity cost is calculated by the price (PELRE), consumption (REEL), and wholesale price index.

Government electricity cost: GVELC

Commercial electricity cost is calculated by the price (PELGV), consumption (GVEL), and wholesale price index.

Final electricity cost: FNELC

Final electricity cost is defined by the sum of the above five sectors' electricity costs.

- Petroleum cost

Agriculture petroleum cost: AGPTC

Agriculture petroleum cost is defined by the diesel's and kerosene's consumptions and prices.

Industry petroleum cost: INPTC

Agriculture petroleum cost is defined by wholesale price, the consumptions of naphtha, diesel, fuel oil, LPG, kerosene and their prices.

Residential/commercial petroleum cost: RCPTC

Agriculture petroleum cost is defined by wholesale price index, LPG, kerosene, diesel and their prices.

Transportation petroleum cost: RCPTC

Transportation petroleum cost is defined by wholesale price index, gasoline, diesel, jet, kerosene, fuel oil and their prices.

Total petroleum cost: TTPTC
Total petroleum cost is defined as the sum of the above four sector's petroleum costs.

- Total energy cost
Total energy cost: TTEC
Total petroleum cost is defined as the sum of the total electricity cost (FNELC) and the total petroleum cost (TTPTC).

Share of total energy cost: TTECS
Share of total energy cost is the share of energy cost in the industrial value added defined by the total energy cost (TTEC) and the total sectoral GDP (GDP.F).

M-2

Model Manual
of
Energy Demand Forecasting Model

JICA Study Team

The Institute of Energy Economics, Japan

M-2

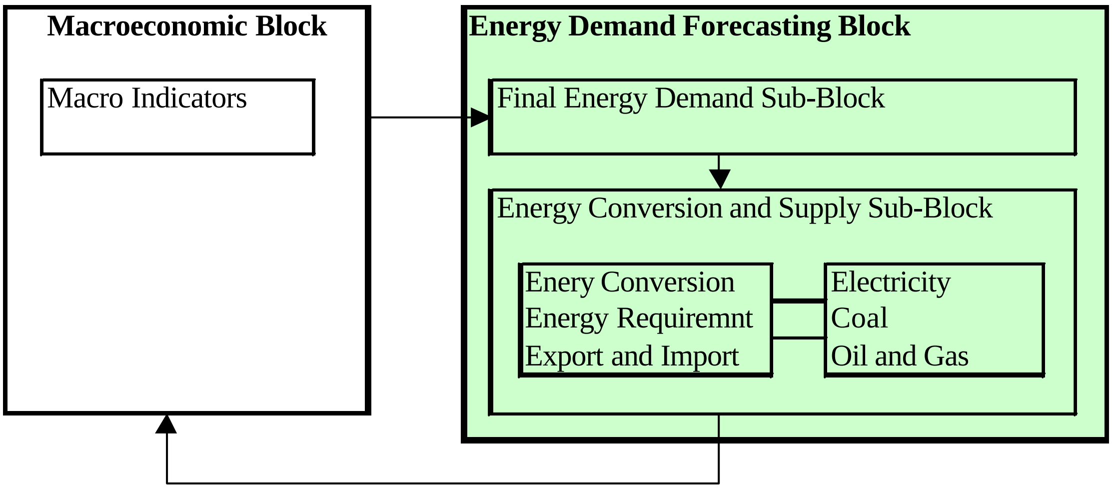
Model Manual of Energy Demand Forecasting Model

1. Calculation Procedure

1.1 Framework of Energy Demand Forecasting Model Block

Energy demand-forecasting model block consists of final energy demand sub-block, energy conversion and supply (energy requirement) sub-block as shown in Figure 1.1.1. 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.

Figure 1.1.1 Schematic Diagram of Energy Demand Forecasting Model Block



1.2 Calculation Step

Figure 1.1.2 shows the general energy flow basing on the category of Energy Balance Table. The model handles the flow of the primary energy requirement, the secondary energy and the final energy demand. Analyzing procedure is progressed from bottom side to upper side, final energy consumption (final energy sub-block), secondary energy supply (energy conversion sub-block) and primary energy supply (energy supply sub-block).

Firstly, calculation is performed in each sector of final energy demand and summarized (First Step). Secondary, conversion sector such as electricity and oil refinery is calculated (Second Step). And after that, primary energy requirement is forecasted taking into consideration of domestic production, partner share, bunker and import/export balance (Third and Forth Step).

1.3 Code Name

Naming of code (abbreviations) is left to modeler's discretion. As a reference, an example is shown in Figure 1.1.3 basing on Energy Balance Table. Each item of columns and rows of Energy Balance Table is defined by two or three characters in the Figure. In this case, sector classification (column) is the first two characters and energy classification (row) is the second two characters, however, such kind of rule is basically free.

Regarding model building, the building work is to fill in each cell of Energy Balance Table for the future by use of historical trends and macro-economic indicators. Therefore code name is defined in only cell classified by Energy Balance Table prepared this time in the Figure. If the classification of the Energy Balance table is made in detail, more many code names of cells could be filled out. Procedure of model building, from First Step to Forth Step, is also shown in Figure 1.1.3.

Figure 1.1.2 General Energy Flow

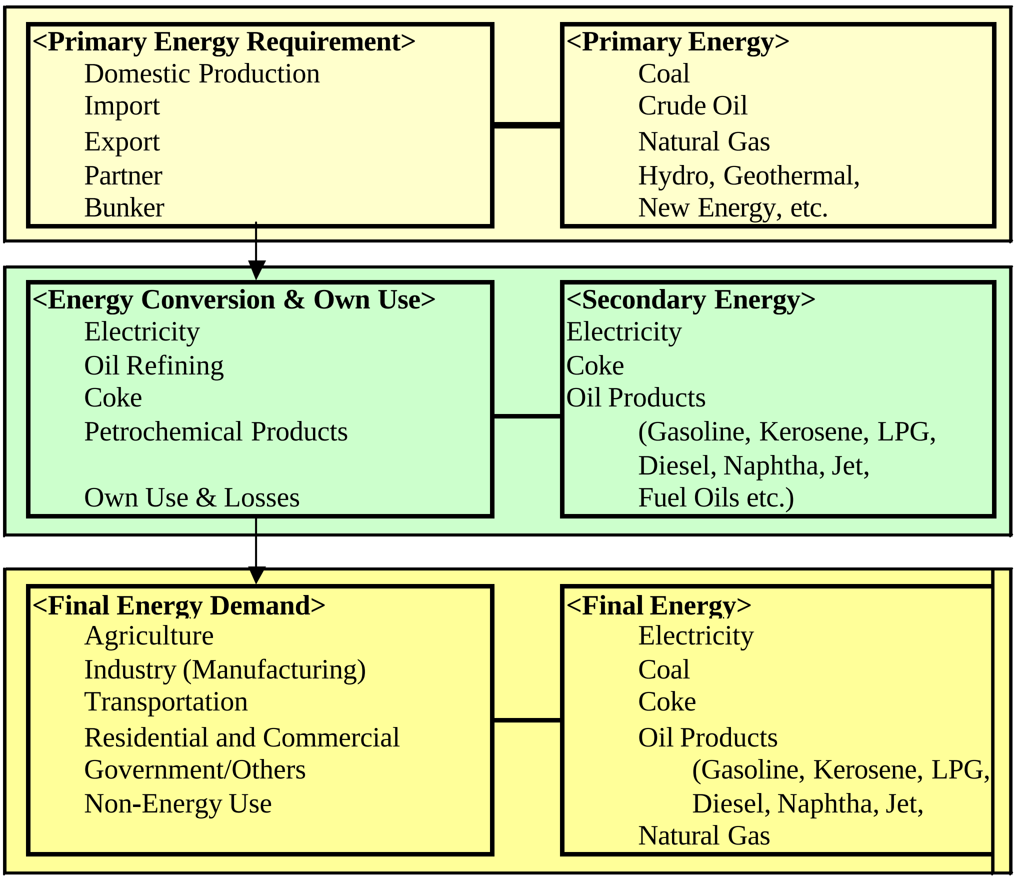


Figure 1.1.3 An Example of Code Name

			Steaming Coal	Coking Coal	Coke	Natural Gas	Crude	NGL	LPG	Gasoline	Jet Fuel	Kerosene	Gas Oil	Fuel Oil	Naphtha	Lubricants	Bitumen	Petroleum Coke	Non-specified	Petroleum Products Total	Fuel Total	Hydro	Thermal	Electricity Total	Total
Fourth Step			SC	CC	CK	NG	CR	NGL	LP	GS	JT	KE	DO	FO	NP	LB	BT	PC	NS	PT	FU	HY	TH	EL	TL
→	Indigenous Production	PD				PDNG	PDCR	PDNGL														PDHY			PDTL
	Import	IM		IMCC					IMLP	IMGS			IMDO			IMLB			IMNS	IMPT					IMTL
	Export	EX			EXCK		EXCR				EXJT			EXFO	EXNP		EXBT			EXPT					EXTL
	To Partner	PAX				PAXNG	PAXCR	PAXNGL																	
	From Partner	PAI				PAING	PAICR	PAINGL																	
	International Marine Bunkers	BN								BNGS	BNJT		BNDO	BNFO		BNLB				BNPT					
Third Step																									
→	Total Primary Energy Supply	PR		PRCC		PRNG	PRCR	PRNGL	PRLP	PRGS	PRJT	PRKE	PRDO	PRFO	PRNP	PRLB	PRBT		PRNS	PRPT		PRHY			PRTL
Second Step	Transfer (LPG)	TS							TSLP																TSTL
→	Total Conversion	CV		CVCC	CVCK	CVNG	CVCR	CVNGL	CVLP	CVGS	CVJT	CVKE	CVDO	CVFO	CVNP	CVLB	CVBT	CVPC	CVNS	CVPT	CVFU	CVHY	CVTH	CVEL	CVTL
	Pub. Electricity (IN)	EL				ELNG							ELDO	ELFO		ELLB				ELPT	ELFU	ELHY			
	Pub. Electricity (OUT)	EL																					ELTH	ELEL	ELTL
	Autoprod. of Electricity																								
	Oil Refineries (IN)	RFI				RFING	RFICR	RFINGL					RFIDO	RFIFO		RFILB				RFIPT					RFITL
	Oil Refineries (OUT)	RF							RFLP	RFGS	RFJT	RFKE	RFDO	RFFO	RFNP	RFLB	RFBT	RFPC	RFNS	RFPT					RFTL
	Petrochemical Industry (IN)	PC				PCNG																			PCTL
	Coke	CK		CKCC	CKCK																				CKTL
	Own Use (Electricity)	OW																						OWEL	
	T/D Losses (Electricity)	LS																						LSEL	
	Statistical Difference	SD			SDSK																				
First Step																									
→	Total Final Energy Consumption	FN			FNCK	FNNG	FNCR	FNNGL	FNLP	FNGS	FNJT	FNKE	FNDO	FNFO	FNNP	FNLB	FNBT	FNPC	FNNC	FNPT	FNFU			FNEL	FNTL
	Agriculture	AG										AGKE	AGDO								AGFU			AGEL	AGTL
	Manufacturing (Industry)	IN			INCK	INNG			INLP			INKE	INDO	INFO			INBT		INNS	INPT	INFU			INEL	INTL
	Food																								
	Textile																								
	Chemicals																								
	Metal & Machinery																								
	Iron & Steel	IS			ISCK																				
	Cement																								
	Transportation	TR								TRGS	TRJT		TRDO	TRFO					TRNS	TRPT	TRFU			TREL	TRTL
	Passenger																								
	Freight																								
	Residential/Commercial	RC				RCNG			RCLP			RCKE	RCDO							RCPT	RCFU			RCEL	RCTL
	Residential	RE																						REEL	
	Commercial	CM																						CMEL	
	Government/Public (Others)	GV																						GVEL	
	Non-Energy	NE				NENG													NENS	NEPC					NETL

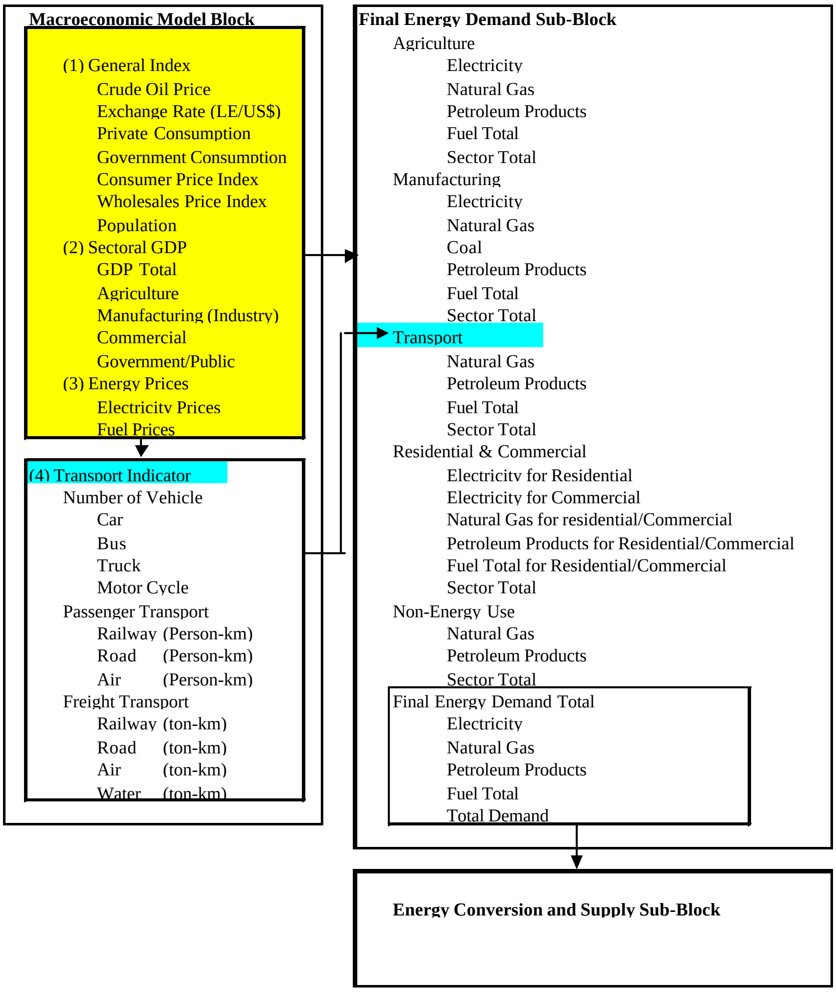
Note: Export, to Partner and (IN) are minus (-) sign in Energy Balance Table

2. Model Structure of Energy Demand Forecasting Block

2.1 Final Energy Demand Sub-Block

Figure 2.1.1 shows the framework of final energy demand sub-block. Macro indicators consist of four items, that is, (1) general index, (2) sectoral GDP, (3) domestic energy prices and (4) transport indicators. In energy demand forecasting sub-block, former three items described above are treated as external valuables in order to simulate the impact of price and GDP growth. Final energy demand sub-block comprising of each sector creates structural equation by energy carrier such as electricity, natural gas and petroleum products (kerosene, LPG, gasoline, diesel oil, fuel oil etc.) and calculates fuel total and sector total. The demand function is estimated by regression analysis in each energy demand for agriculture, manufacturing, transportation, residential/commercial, government/public utilities (others) and non-energy sectors. The final energy demand total is obtained by adding the sector demand.

Figure 2.1.1 Framework of Final Energy Demand Sub-Block



(1) Agricultural Sector

In the model, the energy demand for agricultural use is classified into the electric power and non-electric power (fuels) as shown in Figure 2.1.2. Firstly electricity demand (physical unit, GWh), AGEL, is estimated by regression analysis as the function of GDP component and electricity price. The estimated electricity demand is converted to common unit (ktoe), AGELU. Secondly Kerosene and lubricant is estimated by regression and diesel demand is got by gross trend. And the total demand of petroleum products is calculated. The row of natural gas, which has not been used in agricultural sector, is prepared for the future demand or policy.

Finally fuel total and energy demand total in agricultural sector is defined, and the share of electricity is calculated as shown in the Figure.

Figure 2.1.2 System of Equations in Agricultural Sector

(1) Agriculturral Sector								
Electricity (Physical unit)		GWh	AGEL	$CA	GDPAG A	PELAG/CPIU		
Electricity (Common unit)		ktoe	AGELU	=	AGEL*0.086			
	Diesel	ktoe	AGDO	$TG				
	Kerosene	ktoe	AGKE	$CA	PKERO/CPIU	LAG1 AGKE	DUM.1991	DUM.1994
	Lubricant for Agriculture	ktoe	AGLB	$CA	GDPAG A	PAVE/CPIU	LAG1 AGLB	
Petroleum Product Total		ktoe	AGPT	=	AGDO+AGKE+AGLB			
(Natural Gas)		ktoe	AGNG	=	0			
Fuel Total		ktoe	AGFU	=	AGPT+AGNG-AGLB			
Agricutural Demand Total		ktoe	AGTL	=	AGFU+AGELU+AGLB			
Share of Electricity			SAGEL	=	AGELU/AGTL			

(2) Industrial (Manufacturing) Sector

Figure 2.1.3 shows the system of equations in industrial sector. As for petroleum products, diesel oil, fuel oil, LPG, kerosene, lubricant, bitumen and non-specified petroleum products are now used. Each demand is estimated by regression analysis except fuel oil using gross trend. Rooms for naphtha and petroleum coke are prepared for the future requirement. Petroleum products total is the sum of each product.

Figure 2.1.3 System of Equations in Industrial Sector

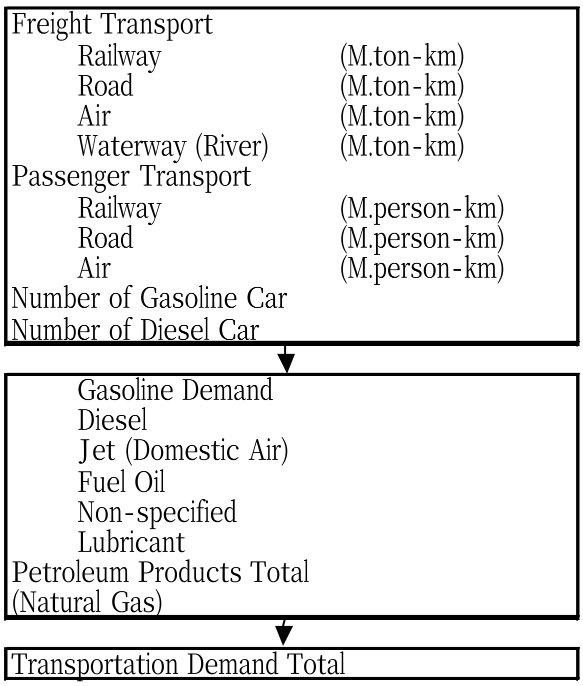
(2) Industrial Sector								
Electricity (Phusical unit)		GWh	INEL	$CA	GDPIN A	PELIN/CPIU	LAG1 INELU	DUM.1994	DUM.1994
Electricity (Common unit)		ktoe	INELU	=	INEL*0.086			
	(Naphtha)	ktoe	INNP	=	0			
	Diesel	ktoe	INDO	$CA	GDPIN A	PDO/PELIN		
	Fuel Oil	ktoe	INFO	$TG				
	LPG	ktoe	INLP	$DL,$CA	GDPIN A	PLPG/CPIU		
	Kerosene	ktoe	INKE	$CA	ln(TREND)			
	Non-specified	ktoe	INNS	$CA	ln(TREND)			
	Lubricant for Industry	ktoe	INLB	$CA	GDPIN A	PAVE/CPIU		
	Bitumen for Industry	ktoe	INBT	$CA	GC	PAVE/CPIU		
	(Petro. Coke)	ktoe	INPC	=	0			
Petroleum Products Total		ktoe	INPT	=	INNP+INDO+INFO+INLP+INKE+INNS+INLB+INBT			
Natural gas		ktoe	INNG	$CA	GDPIN A	LAG1 INNG		
Steel		000 ton	STEEL	$TG				
Coke (Industrial Sector)		ktoe	INCK	$CA	STEEL	PCC*EXR/WPI		
(Coking Coal)		ktoe	INCC	=	0			
(Steaming Coal)		ktoe	INSC	=	0			
Fuel Demand Total		ktoe	INFU	=	INPT+INNG+INCK+INSC+INCC-INLB-INBT			
Industrial Demand Total		ktoe	INTL	=	INFU+INELU+INLB+INBT			
Share of Electricity			SINEL	=	INELU/INTL			

In this case, steel commodity production (STEEL) is introduced for the estimation of coke demand. Steel production should be replaced to crude steel production by blast furnace in the future because coke is used for blast furnace. Coke demand can be input as an external valuable directly basing on the operation and development plan of crude steel manufacturing industry. Rooms are also prepared for coking (metallurgical) coal and steaming (thermal) coal. Finally fuel total and energy demand total in industrial sector is defined, and the share of electricity is calculated as shown in the Figure.

(3) Transportation Sector

Transportation sector is a little bit different from the other sector because of using macro indicators such as freight transport (million ton-km), passenger transport (million person-km), and number of car (gasoline car or diesel car). Figures 2.1.4 (a) and 2.1.4 (b) show the flow of model structure and the system of equations in the transportation sector.

Figure 2.1.4 (a) Flow of Model Structure



Firstly freight and passenger transportation are estimated basing on the analysis flow, and secondly each fuel demand is calculated by use of the estimated indicators of freight and passenger transport. The freight transportation (million ton-km) is basically analyzed by regression using GDP and price except river transport. As for passenger (million person-km), private consumption per capita (PC/POP) and price are used for the regression analysis with lag. In these formula, PC/POP*dum.1990.. is the same as the beginning year 1990 (sample begin of AC column in the model sheet) of the observation year.

Figure 2.1.4 (b) System of Equations in Transportation Sector

(3) Transportation Sector									
(Electricity)			ktoe	TRELU	=	0			
Freight									
	Railway		M. ton-km	TRFRL	$DL,$CA	GDPTR.A	PAVE/PDOTR		
	Road		M. ton-km	TRFRD	$DL,$CA	GDPF.A	PDOTR/WPI	LAG1.TRFRD	
	Air		M. ton-km	TRFAR	$DL,$CA	GDPF.A	PKERO/WPI		
	Waterway (River)		M. ton-km	TRFRV	$TG				
Passenger									
	Railway		M. Person-km	TRPRL	$DL,$CA	PC/POP*DUM.1990..	PDOTR/WPI	LAG1.TRPRL	DUM.1990..
	Road		M. Person-km	TRPRD	$DL,$CA	PC/POP*DUM.1990..	(PGASO+PD(	LAG1.TRPRD	DUM.1990..
	Air		M. Person-km	TRPAR	$DL,$CA	PC/POP*DUM.1990..	PKERO/CPIU	LAG1.TRPAR	DUM.1990..
	Gasoline Car		Number	GCAR	$CA	GDPF.A/POP	TREND		
	Diesel Car		Number	DCAR	$CA	GDPF.A	TREND		
	(Natural Gas)		ktoe	TRNG	=	0			
	Intensity			TRGSI	=	TRGS/GCAR*1000			
				TRGSI	$DL,$CA	PGASO/CPIU	LAG1.TRGSI		
	Gasoline Demand		ktoe	TRGS	=	TRGSI*GCAR/1000			
	Diesel		ktoe	TRDO	$CA	TRFRD+TRFRL	DUM.1996		
	Jet	(Domestic Air)	ktoe	TRJT	$DL,$CA	TRFAR+TRPAR/20	DUM.1989	DUM.1994	DUM.1996
	Fuel Oil		ktoe	TRFO	$CA	ln(TREND)			
	Non-Specified		ktoe	TRNS	$TG				
	Lubricant for Transportation		ktoe	TRLB	$CA	TRFRD+TRPRD/20	PAVE/CPIU	LAG1.TRLB	
Petroleum Products Total			ktoe	TRPT	=	TRGS+TRDO+TRJT+TRFO+TRNS+TRLB			
Fuel Total			ktoe	TRFU	=	TRPT-TRLB+TRNG			
Transportation Total			ktoe	TRTL	=	TRFU+TRELU+TRLB			

Number of gasoline car and diesel car are treated as the function of GDP/capita or GDP and historical trends. In order to obtain gasoline demand (TRGS), intensity of gasoline consumption per car (TRGSI) is estimated by regression analysis and multiplied by the car number (GCAR). Diesel oil demand (TRDO) is obtained from freight transportation of road and railway. Jet fuel demand (TRJT) is obtained from air transportation of freight and passenger. Lubricant demand is obtained from road transportation of fright and passenger. Natural gas and electricity are empty seats for the future.

(4) Residential and Commercial Sector

In residential and commercial sector, electricity is classified into residential and commercial sector. Firstly electricity demand is calculated as shown in Figure 2.1.5 (a). Fuels are for total residential/commercial demand. Natural gas demand is estimated as the function of government consumption, followed by the total demand of petroleum products (in this case, LPG + kerosene) is estimated by GDP and price with lag. After that, LPG and kerosene are separated by use of share function. Basic form of the share is derived from logistic function, Ln(Y/(1-Y))=a+b*X (see APPENDIX).

In this case, SLP/(1-SLP) = a – b*(PLPG/PKERO) + c*(SLP(-1)/(1-SLP(-1)))

Where, SLP = Share of LPG

PLPG = Price of LPG

PKERO = Price of kerosene

SLP(-1) = Lag of SLP

Share of LPG is obtained from SLP/(1-SLP)=A and SLP = A/(1+A). LPG demand is obtained by multiple of the estimated petroleum demand total and the share of LPG. Kerosene demand is obtained by subtract LPG demand from total petroleum demand. Diesel is an empty seat for the future.

Figure 2.1.5 (a) Flow of Model Structure

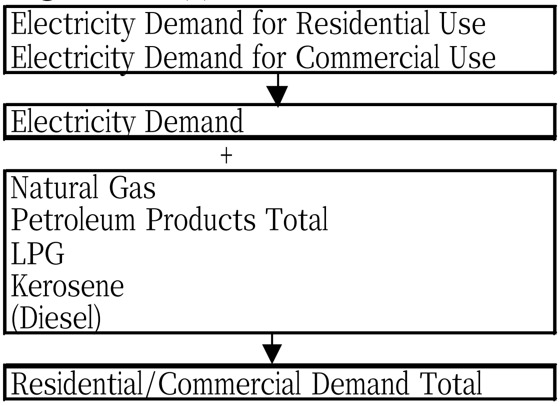


Figure 2.1.5 (b) System of Equations in Residential/Commercial Sector

(4) Residential/Commercial Sector						
Electricity (Residential)	GWh	REEL	$CA	GDPF.A	PELRE/CPIU
Electricity (Commercial)	GWh	CMEL	$DL,$CA	GDPCM.A	PELCM/CPIU
Electricity (Residential & Commercial))	GWh	RCEL	=	REEL+CMEL	
	ktoe	REELU	=	REEL*0.086	
	ktoe	CMELU	=	CMEL*0.086	
	ktoe	RCELU	=	RCEL*0.086	
Natural Gas	ktoe	RCNG	$CA	GC	
Petroleum Products Total	ktoe	RCPT	=	RCLP+RCKE+RCDO	
	ktoe	RCPT	$CA	GDPF.A	(PLPG+PKEFLAG1.RCPT
		SLP	=	RCLP/RCPT	
Share of LPG		SLP/(1-SL	$CA	PLPG/PKERO	LAG1.SLP/(1-LAG1.SLP)
		SLP	=	SLP__1_SLP/(1+SLP__1_SLP)	
LPG	ktoe	RCLP	=	SLP*RCPT	
Kerosene	ktoe	RCKE	=	RCPT-RCLP	
(Diesel)	ktoe	RCDO	=	0	
Commercial Fuel Total	ktoe	RCFU	=	RCNG+RCPT	
R/C Demand Total	ktoe	RCTL	=	RCFU+RCELU	
Share of Electricity		SRCEL	=	RCELU/RCTL	

(5) Government/Public Sector

In government and public sector, only electricity demand is handled in the model. Electricity demand is the function of government consumption and price.

Figure 2.1.6 System of Equations in Government and Public Sector

(5) Government/Public Sector					
Electricity	GWh	GVEL	$CA	GC	PELGV/WPI
	ktoe	GVELU	=	GVEL*0.086	
(Fuel)	ktoe	GVFU	=	0	
Sector Total	ktoe	GVTL	=	GVELU+GVFU	

(6) Non-energy Use

The maximum energy requirement of non-energy use is natural gas. Under the assumption that natural gas is supplied for fertilizer manufacturing, natural gas demand is dependent on the gross trend of GDP component per cropped area. In this case, lubricant is classified into agricultural and industrial sectors and bitumen is into industrial sector, however, lubricant and bitumen can be put in the non-energy use. Items of lubricant and bitumen are prepared in the non-energy sector as shown in Figure.

Figure 2.1.7 System of Equations in Non-Energy Sector

(6) Non-Energy Use								
		Cropped Area			CROP	$TL		
		Intensity (GDPAG/CROP)			CROPI	=	GDPAG/CROP	
					CROPI	$TG		
		Natural Gas		ktoe	NENG	$CA	CROPI	CROP
		Non-specified		ktoe	NENS	$CA	ln(TREND)	
		Petroleum Coke		ktoe	NEPC	$CA	ln(TREND)	
		(Lubricant)		ktoe	NELB	=	0	
		(Bitumen)		ktoe	NEBT	=	0	
	Petroleum Products Total			ktoe	NEPT	=	NENS+NEPC+NEBT+NELB	
	Non-Energy Sector Total			ktoe	NETL	=	NEPT+NENG	

(7) Energy Demand for Water Supply

Items of energy demand for water supply are prepared for the future. If you can get data, you can define each demand in Model sheet, for example, WARO = Intensity * Water required. Where, intensity is defined by plant process and code name of water required is put from the code name of data sheet.

Figure 2.1.8 System of Equations in Water Supply Sector

(7) Energy Demand for Water Supply							
	Electricity						
		Reverse Osmosis	GWh	WARO	=	0	
		Electro-Dialysis	GWh	WAED	=	0	
		Multi-Stage Flash Evaporation	GWh	WAMS	=	0	
		Mechanical Vapor Compresion	GWh	WAMV	=	0	
		Thermo- vapor Compression	GWh	WATV	=	0	
		Electricity Total	GWh	WAEL	=	WARO+WAED+WAMV+WATV	
	Fuel						
		Multi-Stage Flash Evaporation	ktoe	WAMSF	=	0	
		Thermo- vapor Compression	ktoe	WATVF	=	0	
		Fuel Total	ktoe	WAFU	=	WAMSF+WATVF	

(8) Final Energy Demand Total

Figure 2.1.9 shows definition of total final energy demand.

Figure 2.1.9 System of Equations of Final Energy Demand Total

Final Energy Demand Total							
	Total Electricity Demand		GWh	FNEL	=	AGEL+INEL+CMEL+REEL+GVEL+WAEL	
			ktoe	FNELU	=	FNEL*0.086	
	Total Fuel demand		ktoe	FNFU	=	AGFU+INFU+TRFU+RCFU+WAFU	
	Steaming Coal		ktoe	FNSC	=	INSC	
	Coking Coal		ktoe	FNCC	=	INCC	
	Coke		ktoe	FNCK	=	INCK	
	(Crude Oil)		ktoe	FNCR	=	0	
	(NGL)		ktoe	FNNGL	=	0	
	Total Petroleum Products		ktoe	FNPT	=	AGPT+INPT+TRPT+RCPT+NEPT	
		Gasoline	ktoe	FNGS	=	TRGS	
		Diesel	ktoe	FNDO	=	AGDO+INDO+TRDO+RCDO	
		Kerosene	ktoe	FNKE	=	AGKE+INKE+RCKE	
		Jet	ktoe	FNJT	=	TRJT	
		LPG	ktoe	FNLP	=	INLP+RCLP	
		Fuel Oil	ktoe	FNFO	=	INFO+TRFO	
		Bitumen	ktoe	FNBT	=	INBT	
		Lubricant	ktoe	FNLB	=	AGLB+INLB+TRLB	
		Non-specified	ktoe	FNNS	=	INNS+TRNS+NENS	
		Naphtha	ktoe	FNNP	=	INNP	
		Petro. Coke	ktoe	FNPC	=	NEPC	
	Natural Gas		ktoe	FNNG	=	INNG+RCNG+NENG+TRNG+AGNG	
	Energy Demand Total		ktoe	FNTL	=	AGTL+INTL+TRTL+RCTL+GVTL+NETL	
	Share of Electricity			SFNTL	=	FNELU/FNTL	

2.2 Energy Conversion and Energy Supply Sub-Block

Energy conversion and energy supply (energy requirement) sub-block consists of electricity sector, coal sector and oil/gas sector including export and import.

2.2.1 Electricity Sector

Figure 2.2.1 (a) shows the framework of electricity sector. In this sector, total electricity demand forecasted is received from the final energy sub-block. Adding transmission /distribution (T/D) losses and own use (in plant use), the total electric power generation required is calculated. Thermal power generation is obtained by subtracting hydropower generation from the total. Total and each fuel demand are obtained by use of thermal efficiency and fuel share function.

In this short-medium term forecasting model, all variables are set as internal variables. From the technical point of view, the ratios of T/D loss and own use, hydropower generation and thermal efficiency can be input as external variables. In the case of medium-long term forecasting model, the model should uptake the figures national power development plan including hydropower and gas thermal power as external valuables.

Figure 2.2.1 (a) Framework of Electricity Sector

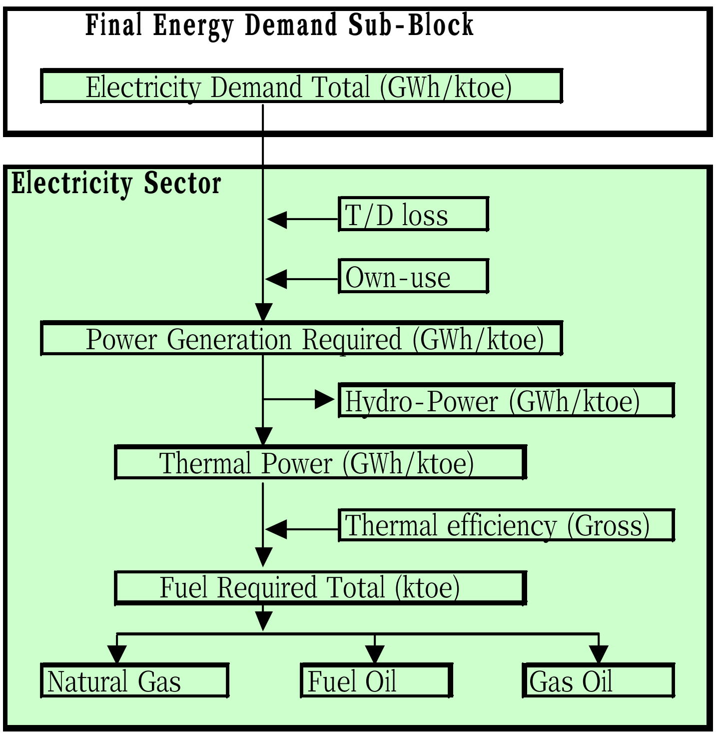


Figure 2.2.1 (b) shows the system of equations in electricity sector. Firstly the ratio of own use (SOWEL) and the ratio of T/D losses (SLSEL) are estimated as linear trends, however, it is better to input these technical valuables as external valuables than internal valuables. Secondly own use (OWEL) and T/D losses (LSEL) are calculated by use of SOWEL and SLSEL. Required electric power generation (ELEL) is got from final energy demand (FNEL) and losses just described above.

Hydropower generation (ELHY) is assumed by historical trend, however, hydropower should be input as an external valuable basing on hydropower development plan. Thermal power generation (ELTH) is obtained by subtracting hydropower generation from the required power (ELEL).

The required fuel total for thermal power (ELFU) is calculated by use of thermal efficiency (ELEFF), which is given by lag1.ELEFF (fixed at previous year’s value). The ELEFF can be input as an external valuable according to power development plan. Of the fuel total, natural gas demand (ELNG) is obtained by the share function foam of SELNG/(1–SELNG) = f(ln(TREND)), where SELNG means the share of natural gas. Petroleum products total for the thermal power is obtained by subtracting natural gas demand from the furl total required. Next, diesel oil and fuel oil demand are calculated as shown in Figure 2.2.1 (b). These fuel mix can be given as external valuables. Lubricant demand for electricity sector (ELLB) is estimated by the share (SELB) of ELLB/ELEL. Item of steaming coal (ELSC) is an empty seat for coal thermal power in the future.

Figure 2.2.1 (b) System of Equations in Electricity Sector

Electricity Sector					
	Ratio of Own Use		SOWEL	$TL	
	Ratio of T/D Loss		SLSEL	$TL	
	Own Use	GWh	OWEL	=	SOWEL*ELEL
	T/D Losse	GWh	LSEL	=	SLSEL*ELEL
	Power Generation	GWh	ELEL	=	FNEL/(1-SOWEL-SLSEL)
	Hydro Power	GWh	ELHY	$CA	Ln(TREND)
	New Energy	GWh	ELNEW	=	0
	Thermal Power	GWh	ELTH	=	ELEL-ELHY-ELNEW
	Power Generation (Common unit)	ktoe	ELELU	=	ELEL*0.086
	Hydro Power	ktoe	ELHYU	=	ELHY*0.086
	Thermal Power	ktoe	ELTHU	=	ELTH*0.086
	Own Use	ktoe	OWELU	=	OWEL*0.086
	T/D Losse	ktoe	LSELU	=	LSEL*0.086
	Total Losses	ktoe	ELOSU	=	ELELU-FNELU
	Thermal Efficiency (Gross)		ELEFF	=	LAG1.ELEFF
	Fuel Total Required	ktoe	ELFU	=	ELTHU/(ELEFF)
	Share of Natural Gas		SELNG	=	ELNG/ELFU
			SELNG/(1-SELNG)		ln(TREND)
			SELNG	=	SELNG__1_SELNG/(1+SELNG__1_SELNG)
	Natural Gas	ktoe	ELNG	=	SELNG*ELFU
	Petroleum Products Total	ktoe	ELPT	=	ELFU-ELNG
	Diesel Oil	ktoe	ELDO	$TG	
	Fuel Oil	ktoe	ELFO	=	ELPT-ELDO
	Steaming Coal	ktoe	ELSC	=	0
	Share of Lubricant		SELB	$TL	
	Lubricant		ELLB	=	SELB*ELEL
	Electricity Sector Total		ELTLU	=	ELTHU-ELHYU-ELFU-ELLB

2.2.2 Coal Sector

Figure 2.2.2 (a) shows the framework of coal sector. In coal sector as well, coke demand is received from the final energy sub-block. Main purpose of this sector is to obtain coking coal (metallurgical coal) demand. As for steaming coal (thermal coal), both production and consumption (or export) are small amount at present. While all variables are treated as internal valuables in this model, coke export, steaming coal export and conversion factor from coking coal to coke can be set intentionally as external valuables. Coke produced is supplied to domestic market (industrial sector) and foreign market.

Figure 2.2.2 (a) Framework of Coal Sector

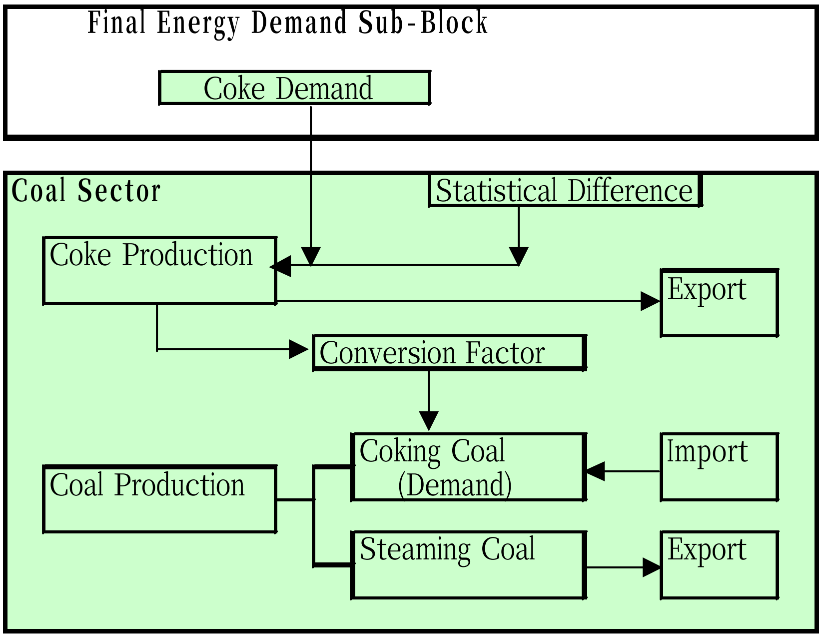


Figure 2.2.2 (b) System of Equations in Coal Sector

Coal sector						
Steaming Coal Production	ktoe		PDSC	=	(LAG1.PDSC+lag2.PDSC+lag3.PDSC+lag4.PDSC)/4
Coking Coal Production	ktoe		PDCC	=	0
Statistical Difference	ktoe	(External)	SDCK	$CA	ln(TREND)
Conversion Ratio	ktoe	(External)	CCRT	$CA	ln(TREND)
Coke Production	ktoe		CKCK	=	FNCK+EXCK+SDCK
Coking Coal Suppy to Coke Oven	ktoe		CKCC	=	CKCK/CCRT
Coke Total			CKTL	=	CKCK-CKCC
Steaming Coal Import	ktoe		IMSC	=	0
Steaming Coal Export	ktoe		EXSC	=	PDSC
Coking Coal Import	ktoe		IMCC	=	CKCC
Coking Coal Export	ktoe		EXCC	=	0
Coke Import	ktoe		IMCK	=	0
Coke Export	ktoe	(External)	EXCK	=	LAG1.EXCK

Figure 2.2.2 (b) shows the system of equations in coal sector. Firstly steaming coal production (PDSC) is assumed as the average value of last four years. Steaming coal is also assumed to be exported, that is, EXSC=PDSC. As coking coal has not produced

domestically, the indigenous production (PDCC) is defined as zero (PDCC=0).

Secondly coke production (CKCK) is estimated from final coke demand (FNCK) and export (EXCK) taking into consideration of statistical difference (SDCK). EXCK id defined as lag1.EXEK. And then coking coal demand (CKCC) is calculated by use of conversion factor (CCRT) from coking coal to coke in blast furnaces. In this model, CCRT is assumed to be the function of trend, however, CCRT can be input as an external valuable because of technical indicator. Steaming coal import (IMSC), coking coal export (EXCC) and coke import (IMCK) are prepared for the future.

2.2.3 Oil and Gas Sector

Figure 2.2.3 (a) shows the framework of oil and gas sector. In this sector, oil refining plays an important role. Benchmark of oil refineries' operation is assumed to meet domestic petroleum products' total demand and the petroleum products total is received from the final energy demand sub-block. Firstly refineries' products (output) total is forecasted basing on the past trend of refineries' products total and its domestic demand total. After the determination of the refineries' output, the required amount of throughput and fuel etc. is forecasted. Refineries' output of each petroleum products is obtained by use of yield of each product. Yield also can be input as external valuables.

Indigenous production of natural gas and NGL are assumed to meet the total domestic demand in order to avoid mismatch between supply and demand (especially export/import) in this stage. Taking into consideration of indigenous production, partner share and bunker stock, export and import are calculated. Getting both of natural gas and NGL in and out from partner is balanced in each. The in and out of crude oil from partner is calculated by the share function obtained from the past trend. Crude oil production is forecasted by regression analysis and is balanced in terms of export and import. The balance of petroleum products is also taken into consideration in terms of in the export/import term.

(1) Oil Refinery Sector

Figure 2.2.3 (b) shows the system of equations in oil refinery sector. Firstly the ratio of refinery output (RFPT) and final demand (FNPT) of petroleum products is defined as SRFFN=RFPT(-1)/FNPT(-1) and the output (RFPT) is obtained by the multiplication of SRFFN and FNPT.

Secondly throughput total to refineries (RFIOIL) is obtained by use of the ratio of throughput and refinery output (RFIOIL(-1)/RFPT(-1)). And from the share of NGL to throughput, crude oil and NGL are calculated.

Thirdly fuel input total to refineries (RFIFU) is obtained by the ratio of input fuel and throughput (RFIFU(-1)/RFIOIL(-1)). And then the share of natural gas to fuel input total (SNG) is estimated by the share function form of SNG/(1-SNG) = f (PNG/(PDO+PFO), SNG(-1)/(1-SNG(-1)), where PNG, PDO and PFO mean price of natural gas, price of diesel oil and price of fuel oil respectively. Next diesel oil and fuel oil's requirement is got by subtraction natural gas from fuel input total. Diesel oil and fuel oil are segregated by the share.

Lubricant demand for refineries' use is got from the ratio to throughput.

Figure 2.2.3 (a) Framework of Oil and Gas Sector

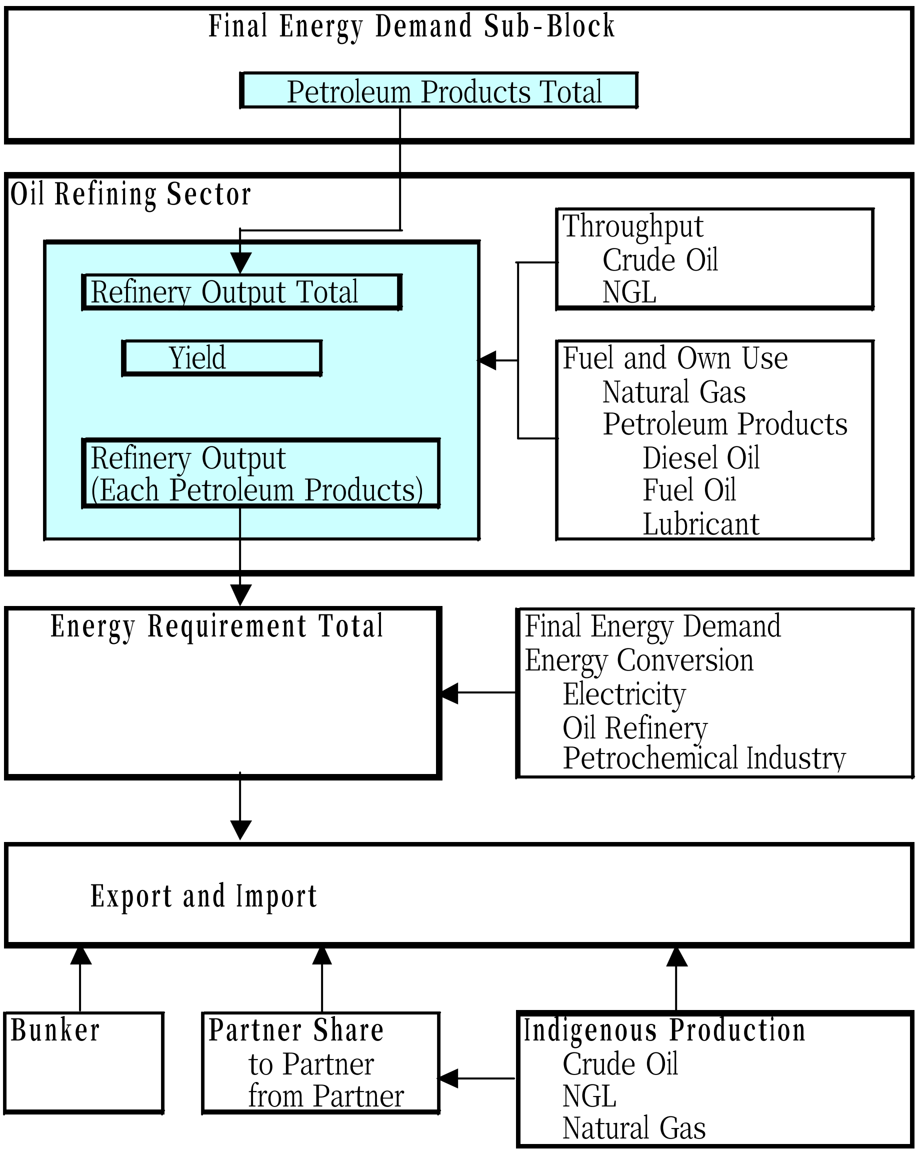


Figure 2.2.3 (b) System of Equations in Oil Refinery Sector

Section	Item	Note	Unit		Variable	Op	Equation	Extra
Oil Refining Sector								
	Ratio of Refinery Output/Final Demand (RFPT/FNPT)				SRFFN	=	LAG1.RFPT/LAG1.FNPT	
	Products (Output) Total		ktoe		RFPT	=	FNPT*SRFFN	
			ktoe		RFTL	=	RFPT	
	Ratio of Throughput/Refinery Output (RFIOIL/RFPT)				SRFIO	=	LAG1.RFIOIL/LAG1.RFPT	
	Throughput Total		ktoe		RFIOIL	=	SRFIO*RFPT	
	Share of NGL	RFINGL/(RFINGL+RFICR)			SNGL	=	LAG1.RFINGL/(LAG1.RFINGL+LAG1.RFICR)	
	Crude Oil		ktoe		RFICR	=	RFIOIL*(1-SNGL)	
	NGL		ktoe		RFINGL	=	RFIOIL*SNGL	
	Ratio of Fuel/Throughput	RFIFU/RFIOIL			STFU	=	LAG1.RFIFU/LAG1.RFIOIL	
	Fuel Total		ktoe		RFIFU	=	RFIOIL*STFU	
	Share of Natural Gas/Fuel Total	RFING/RFIFU			SNG/(1-SNG)	$CA	PNG/(PDO+PFO)	LAG1.SNG/(1-LAG1.SNG)
					SNG	=	SNG__1_SNG/(1+SNG__1_SNG)	
	Natural Gas		ktoe		RFING	=	SNG*RFIFU	
	Input (Diesel Oil + Fuel Oil)		ktoe		RFIDF	=	RFIFU-RFING-RFILB	
	Share of Diesel /(Diesel+Fuel Oil)				SDO	$TG		
	Diesel Oil		ktoe		RFIDO	=	SDO*RFIDF	
	Fuel Oil		ktoe		RFIFO	=	RFIDF-RFIDO	
	Ratio of Lubricant/Throughput		%		STLB	=	LAG1.RFILB/LAG1.RFIOIL	
	Lubricant		ktoe		RFILB	=	RFIOIL*STLB/100	
	Petro. Total		ktoe		RFIPT	=	RFIDO+RFIFO+RFILB	
	Input Total				RFITL	=	RFING+RFICR+RFINGL+RFIPT	
Yield				(External)				
	LPG				YLP	=	LAG1.YLP	
	Gasoline				YGS	=	LAG1.YGS	
	Jet Fuel				YJT	=	LAG1.YJT	
	Kerosene				YKE	=	LAG1.YKE	
	Gas/Diesel Oil				YDO	=	LAG1.YDO	
	Fuel Oil				YFO	=	LAG1.YFO	
	Naphtha				YNP	=	LAG1.YNP	
	Lubricants				YLB	=	LAG1.YLB	
	Bitumen				YBT	=	LAG1.YBT	
	Petroleum Coke				YPC	=	LAG1.YPC	
	Non-specified				YNS	=	LAG1.YNS	
Output								
	Thruoghput		ktoe		RFI	=	RFIOIL	
	LPG		ktoe		RFLP	=	RFI*YLP	
	Gasoline		ktoe		RFGS	=	RFI*YGS	
	Jet Fuel		ktoe		RFJT	=	RFI*YJT	
	Kerosene		ktoe		RFKE	=	RFI*YKE	
	Gas/Diesel Oil		ktoe		RFDO	=	RFI*YDO	
	Fuel Oil		ktoe		RFFO	=	RFI*YFO	
	Naphtha		ktoe		RFNP	=	RFI*YNP	
	Lubricants		ktoe		RFLB	=	RFI*YLB	
	Bitumen		ktoe		RFBT	=	RFI*YBT	
	Petroleum Coke		ktoe		RFPC	=	RFI*YPC	
	Non-specified		ktoe		RFNS	=	RFI*YNS	

(2) Petrochemical Industry and Transfer Sector

Natural gas is used as raw material in petrochemical industry. Under the assumption that natural gas is used for fertilizer manufacturing, natural gas demand is calculated as the function of crop area (CROP) and intensity to GDP component of crop area (CROPI) as shown in Figure 2.2.3 (c).

LPG transfer from oil/gas field is assumed as the ratio of LPG transfer and crude production (PDOIL).

Figure 2.2.3 (c) System of Equations in Petrochemical Industry and Transfer Sector

Section	Item	Unit	Variable	Op	Equation	Extra
Petrochemical Industry						
	Natural Gas	ktoe	PCNG	$CA	CROPI	CROP
	Total	ktoe	PCTL	=	PCNG	
Transfer						
	Ratio of LPG/Crude		STSLP	=	TSLP/PDOIL	
			STSLP	$TL		
	LPG	ktoe	TSLP	=	STSLP*PDOIL	
			TSTL	=	TSLP	

2.2.4 Primary Energy Supply and Secondary Energy Requirement

The model summarizes total energy requirement (total domestic demand), through the final energy demand sub-block, the conversion sector including electricity, oil refining, petrochemical industry and transfer (LPG), and the primary energy supply sector.

(1) Primary Energy and Secondary Energy Requirements

Figure 2.2.4 (a) shows the summarized primary energy requirement (domestic supply) of coal, natural gas, crude oil and NGL, and the balancing of petroleum products in "Energy Balance Table".

Figure 2.2.4 (a) Primary Energy Supply and Balance

Primary Energy Supply and Balance				
Steaming Coal	ktoe	PRSC	=	FNSC
Coking Coal	ktoe	PRCC	=	FNCC+CKCC
Natural Gas	ktoe	PRNG	=	FNNG+ELNG+RFNG+PCNG
Crude Oil	ktoe	PRCR	=	FNCR+RFICR
NGL	ktoe	PRNGL	=	FNNGL+RFNGL
Crude (Crude Oil + NGL)	ktoe	PROIL	=	PRCR+PRNGL
LPG	ktoe	PRLP	=	FNLP-RFLP-TSLP
Gasoline	ktoe	PRGS	=	FNGS-RFGS
Jet	ktoe	PRJT	=	FNJT-RFJT
Kerosene	ktoe	PRKE	=	FNKE-RFKE
Diesel	ktoe	PRDO	=	FNDO-(RFDO-ELDO-RFIDO)
Fuel OIL	ktoe	PRFO	=	FNFO-(RFFO-ELFO-RFIFO)
Naphtha	ktoe	PRNP	=	FNNP-RFNP
Lubricant	ktoe	PRLB	=	FNLB-(RFLB-ELLB-RFILB)
Bitumen	ktoe	PRBT	=	FNBT-RFBT
Petro. Coke	ktoe	PRPC	=	FNPC-RFPC
Non-specified	ktoe	PRNS	=	FNNS-RFNS
Petro. Total	ktoe	PRPT	=	PRLP+PRGS+PRJT+PRKE+PRDO+PRFO+PRNP+PRLB+PRBT+PRPC+PRNS

(2) Domestic Secondary Energy Requirement

Figure 2.2.4 (b) summarizes the secondary energy requirement for domestic use.

Figure 2.2.4 (b) Secondary Energy Requirement

Domestic Secondary Energy Requirement				
LPG	ktoe	DMLP	=	FNLP
Gasoline	ktoe	DMGS	=	FNGS
Jet	ktoe	DMJT	=	FNJT
Kerosene	ktoe	DMKE	=	FNKE
Diesel	ktoe	DMDO	=	FNDO+ELDO+RFIDO
Fuel OIL	ktoe	DMFO	=	FNFO+ELFO+RFIFO
Naphtha	ktoe	DMNP	=	FNNP
Lubricant	ktoe	DMLB	=	FNLB+ELLB+RFILB
Bitumen	ktoe	DMBT	=	FNBT
Petro. Coke	ktoe	DMPC	=	FNPC
Non-specified	ktoe	DMNS	=	FNNS
Petro. Total	ktoe	DMPT	=	DMLP+DMGS+DMJT+DMKE+DMDO+DMFO+DMNP+DMLB+DMPC+DMNS
Fuel Total	ktoe	DMFU	=	DMPT-DMLB-DMBT
Electricity	ktoe	DMEL	=	ELELU
Energy Requirement Total	ktoe	DMTL	=	DMEL+DMPT+PRSC+PRCC+PRNG

2.2.5 Indigenous Production

Figure 2.2.5 shows the domestic production of natural gas, NGL and crude oil. In principle, these important energy productions should be input as external valuables according to national development plan. In this case, the productions of natural gas and NGL are assumed to be met the estimated domestic demand/requirement. As for crude oil, the production is estimated as the function of price and actual value of previous year (PDCR(-1)).

Figure 2.2.5 System of Equations of Indigenous Production

Indigenous Production								
*	Natural Gas	ktoe	(External)	PDNG	=	PRNG		
*	NGL	ktoe	(External)	PDNGL	=	PRNGL		
*	Crude Oil	ktoe	(External)	PDCR	$DL,$CA	PCR/USDEF	LAG1.PDCR	
	Crude Oil + NGL	ktoe		PDOIL	=	PDNGL+PDCR		
	Production Total	ktoe		PDTL	=	PDNG+PDCR+PDNGL		

2.2.6 Partner Share

Each partner's share of natural gas, crude oil and NGL is inferred to be basing on contracts with foreign counterparts. In this case, however, the share is estimated by share function of logistic type as shown in Figure 2.2.6.

Regarding the buy-back from partner, both of natural gas and NGL are repurchased all from partners. On the other hand, crude oil is assumed to be repurchased basing on the past trend.

Figure 2.2.6 System of Equations of Partner Share

Partner Share to Partner									
	Natural Gas				SPANG	=	PAXNG/PDNG		
		Share			SPANG/(1-SPAI	$CA	PCR/USDEF	LAG1.SPANG/(1-LAG1.SPANG)	
					SPANG	=	SPANG__1_SPANG/(1+SPANG__1_SPANG)		
		to Partner	ktoe		PAXNG	=	SPANG*PDNG		
	Crude Oil				SPACR	=	PAXCR/PDCR		
		Share			SPACR/(1-SPA	$CA	PCR/USDEF	LAG1.SPACR/(1-LDUM.1985	DUM.1995
					SPACR	=	SPACR__1_SPACR/(1+SPACR__1_SPACR)		
		to Partner	ktoe		PAXCR	=	SPACR*PDCR		
	NGL				SPANGL	=	PAXNGL/PDNGL		
		Share			SPANGL/(1-SP/	$DL,$CA	PCR/USDEF	LAG1.SPANGL/(1-LAG1.SPANGL)	
					SPANGL	=	SPANGL__1_SPANGL/(1+SPANGL__1_SPANGL)		
		to Partner	ktoe		PAXNGL	=	SPANGL*PDNGL		
	to Partner Total		ktoe		PAXTL	=	PAXNG+PAXCR+PAXNGL		
From Partner									
	Natural Ga	from Partner	ktoe		PAING	=	PAXNG		
	Crude Oil				SPCR	=	PAICR/(PAXCR)		
		Share			SPCR	$TL			
		from Partner	ktoe		PAICR	=	SPCR*PAXCR		
	NGL	from Partner	ktoe		PAINGL	=	PAXNGL		
	from Partner Total				PAITL	=	PAING+PAICR+PAINGL		

2.2.7 Bunker of Petroleum Products

Jet fuel and fuel oil adopts the average value of last five years, and fuel oil and lubricant adopt the previous year's values. Banker balance is introduced for the calculation of import and export. Bunker petroleum products such as gasoline, jet fuel, diesel oil and fuel oil are treated as the primary supply balance like PRGSI=PRGS+BNGS, for convenience.

Figure 2.2.7 System of Equation of Bunker

Bunker					(External)			
	*	Gasoline		ktoe		BNGS	=	0
	*	Jet		ktoe		BNJT	=	(LAG1.BNJT+lag2.BNJT+lag3.BNJT+lag4.BNJT+lag5.BNJT)/5
	*	Diesel Oil		ktoe		BNDO	=	LAG1.BNDO
	*	Fuel Oil		ktoe		BNFO	=	(LAG1.BNFO+lag2.BNFO+lag3.BNFO+lag4.BNFO+lag5.BNFO)/5
	*	Lubricant		ktoe		BNLB	=	LAG1.BNLB
		Bunker Total		ktoe		BNTL	=	BNGS+BNJT+BNDO+BNFO+BNLB
	Bunker balance		Gasoline	ktoe		PRGSI	=	PRGS+BNGS
			Jet	ktoe		PRJTI	=	PRJT+BNJT
			Diesel Oil	ktoe		PRDOI	=	PRDO+BNDO
			Fuel Oil	ktoe		PRFOI	=	PRFO+BNFO
			Labricant	ktoe		PRLBI	=	PRLB+BNLB

2.2.8 Import and Export in Oil and Gas Sector

Import or export is defined as minus (-) or plus (+) of the difference between production and domestic requirement including partner share and bunker.

If Primary Energy Supply – Production + (to Partner – from Partner) > 0, Import

If Primary Energy Supply – Production + (to Partner – from Partner) < 0, Export

Taking an example of natural gas,

If PRNG – PDNG + (PAXNG – PAING) > 0, Import

If PRNG – PDNG + (PAXNG – PAING) > 0, Export

Petroleum products without partner's share and bunker stock are simple;

If Primary Energy Supply (balance) > 0 or <0, Import or Export

For instant, If PRLP > 0 or <0, Import or Export

Figure 2.2.8 System of Equations of Import and Export

Import and Export (incld. Stock)						
Natural Gas			ktoe	XING	=	PRNG-PDNG+(PAXNG-PAING)
		Import	ktoe	IMNG	=	IF(XING>=0,XING,0)
		Export	ktoe	EXNG	=	IF(XING<0,abs(XING),0)
Crude Oil			ktoe	XICR	=	PRCR-PDCR+(PAXCR-PAICR)
		Import	ktoe	IMCR	=	IF(XICR>=0,XICR,0)
		Export	ktoe	EXCR	=	IF(XICR<0,abs(XICR),0)
NGL			ktoe	XINGL	=	PRNGL-PDNGL+(PAXNGL-PAINGL)
		Import	ktoe	IMNGL	=	IF(XINGL>=0,XINGL,0)
		Export	ktoe	EXNGL	=	IF(XINGL<0,abs(XINGL),0)
	LPG	Import	ktoe	IMLP	=	IF(PRLP>=0,PRLP,0)
		Export	ktoe	EXLP	=	IF(PRLP<0,abs(PRLP),0)
	Gasoline	Import	ktoe	IMGS	=	IF(PRGSI>=0,PRGSI,0)
		Export	ktoe	EXGS	=	IF(PRGSI<0,abs(PRGSI),0)
	Jet	Import	ktoe	IMJT	=	IF(PRJTI>=0,PRJTI,0)
		Export	ktoe	EXJT	=	IF(PRJTI<0,abs(PRJTI),0)
	Kerosene	Import	ktoe	IMKE	=	IF(PRKE>=0,PRKE,0)
		Export	ktoe	EXKE	=	IF(PRKE<0,abs(PRKE),0)
	Diesel	Import	ktoe	IMDO	=	IF(PRDOI>=0,PRDOI,0)
		Export	ktoe	EXDO	=	IF(PRDOI<0,abs(PRDOI),0)
	Fuel OIL	Import	ktoe	IMFO	=	IF(PRFOI>=0,PRFOI,0)
		Export	ktoe	EXFO	=	IF(PRFOI<0,abs(PRFOI),0)
	Naphtha	Import	ktoe	IMNP	=	IF(PRNP>=0,PRNP,0)
		Export	ktoe	EXNP	=	IF(PRNP<0,abs(PRNP),0)
	Lubricant	Import	ktoe	IMLB	=	IF(PRLBI>=0,PRLBI,0)
		Export	ktoe	EXLB	=	IF(PRLBI<0,abs(PRLBI),0)
	Bitumen	Import	ktoe	IMBT	=	IF(PRBT>=0,PRBT,0)
		Export	ktoe	EXBT	=	IF(PRBT<0,abs(PRBT),0)
	Petro. Cok	Import	ktoe	IMPC	=	IF(PRPC>=0,PRPC,0)
		Export	ktoe	EXPC	=	IF(PRPC<0,abs(PRPC),0)
	Non-specif	Import	ktoe	IMNS	=	IF(PRNS>=0,abs(PRNS),0)
		Export	ktoe	EXNS	=	IF(PRNS<0,PRNS,0)
Petro. Total		Import	ktoe	IMPT	=	IF(PRPT>=0,PRPT,0)
		Export	ktoe	EXPT	=	IF(PRPT<0,abs(PRPT),0)
Import Total			ktoe	IMTL	=	IMCC+IMNG+IMCR+IMNGL+IMPT
Export Total			ktoe	EXTL	=	EXCK+EXNG+EXCR+EXNGL+EXPT
Balance of Import and Export			ktoe	BATL	=	IMTL-EXTL

2.2.9 Intensity

At last, main intensities by consumption sector are calculated as shown in Figure 2.2.9. If you want other intensities, you can define.

Figure 2.2.9 Main Intensities by Sector

Intensity with respect to GDP by Sector				
	Electricity Consumption	IFNEL	=	FNEL/GDPF.A
	Electricity Generation	IELEL	=	ELEL/GDPF.A
	Energy Requirement	IDMTL	=	DMTL/GDPF.A
	Final Energy Consumption	IFNTL	=	FNTL/GDPF.A
	Agriculture	IAGTL	=	AGTL/GDPAG.A
	Industry	INTL	=	INTL/GDPIN.A
	Transportation	ITRTL	=	TRTL/GDPTR.A
	Residential/Commercial	IRCTL	=	RCTL/GDPF.A
	Government/Public	IGVTL	=	GVTL/GDPGV.A

3. Application

3.1 Energy Conservation Target

The model is designed to get energy conservation targets input intentionally for the case of data unavailability. Column AE "Replace in Sim" in Model Sheet is prepared for the simulation of such kind of targets. If you want to introduce annual energy conservation target of 2%, you can handle as $Y*(1-0.02)^(trend-18). Where, $Y means simulation result and trend represents time trend of Data Sheet and Simulation Sheet, that is, trend = 18 is base year 1998. If data of 1999 are input, you have to change to $Y*(1-0.02)^(trend-19).

Figure 3.1.1 Column AE in Model Sheet

1982	1997	$Y*(1-.00)^(trend-18)	OLS: R.998; AR.997; DW1.67; F1183.9; DF10(p5%R.91/F19.4/t2.23); RSS3
1981	1998		Definition
1981	2005		Definition
1981	1998	$Y*(1-.00)^(trend-18)	OLS: R.882; AR.866; DW1.42; F56.1; DF15(p5%R.72/F19.43/t2.13); RSS33
1981	1998		Direct
1981	1997	$Y*(1-.00)^(trend-18)	OLS: R.973; AR.969; DW1.37; F259; DF14(p5%R.74/F19.42/t2.14); RSS.17
1981	1998	$Y*(1-.00)^(trend-18)	OLS: R.619; AR.595; DW.47; F26.1; DF16(p5%R.55/F19.43/t2.12); RSS22.
1981	1998	$Y*(1-.00)^(trend-18)	OLS: R.866; AR.858; DW1.39; F103.8; DF16(p5%R.55/F19.43/t2.12); RSS1
1988	1997	$Y*(1-.00)^(trend-18)	OLS: R.848; AR.805; DW2.35; F19.6; DF7(p5%R.85/F19.35/t2.36); RSS39.
1988	1997	$Y*(1-.00)^(trend-18)	OLS: R.857; AR.816; DW2.68; F21; DF7(p5%R.85/F19.35/t2.36); RSS4917.

In principle, energy conservation policy involves scenarios and data as well. The easiest way to discuss energy conservation policies and targets on energy demand side is to consider them from intensity or productivity aspects. This, however logically, requires such time-series data as shown in Tables 3.1.1 and 3.1.2. As for energy conservation on energy supply side, data available from EEA and EGPC can be input as exogenous values. If OEP prepare intensity of each energy source (fuel), you can evaluate energy conservation target or potential through cross-country analysis.

Table 3.1.1 Example of Data to evaluate Energy Intensities (Industry)

Industrial Sector	Production (or IIP)	Energy Consumption (example)						
		Electricity	N.G	LPG	Kerosene	Gas Oil	Fuel Oil	Coal
Pig iron								
Cement								
Chemical								
Food								
Textile								
Non-ferrous								
Mechanics								

Table 3.1.2 Example of Data to evaluate Energy Intensities (Residential/Commercial)

Residential Commercial	Floor Space	Energy Consumption (example)						
		Electricity	Town Gas	LPG	Kerosene	Solar Others		
Heating								
Cooling								
Hot Water								
Cooking								
Power etc.								

3.2 Fuel Shift to Natural Gas

3.2.1 Scenario Control

Figure 3.2.1 shows the example of fuel shift from diesel oil to natural gas (5% annually) in industrial sector. We can also use column AE in Model Sheet.

Figure 3.2.1 Example of Fuel Shift

(2) Industrial Sector						
Electricity (Phusical unit)	GWh	INEL	$CA	1982	1997	$Y*(1-.00)^(trend-18)
Electricity (Common unit)	ktoe	INELU	=	1981	1998	
(Naphtha)	ktoe	INNP	=	1981	2005	
Diesel	ktoe	INDO	$CA	1981	1998	$Y*(1-.05)^(trend-18)
Fuel Oil	ktoe	INFO	$TG	1981	1998	
LPG	ktoe	INLP	$DL,$CA	1981	1997	$Y*(1-.00)^(trend-18)
Kerosene	ktoe	INKE	$CA	1981	1998	$Y*(1-.00)^(trend-18)
Non-specified	ktoe	INNS	$CA	1981	1998	$Y*(1-.00)^(trend-18)
Lubricant for Industry	ktoe	INLB	$CA	1988	1997	$Y*(1-.00)^(trend-18)
Bitumen for Industry	ktoe	INBT	$CA	1988	1997	$Y*(1-.00)^(trend-18)
(Petro. Coke)	ktoe	INPC	=	1981	2005	
Petroleum Products Total	ktoe	INPT	=	1981	1998	
Natural gas	ktoe	INNG	$CA	1982	1998	$Y+(SimOrig!INDO-INDO)

In this case, $Y*(1-0.05)^(trend-18) means 5% decrease of diesel oil demand annually and shift the decrement to natural gas through $Y+(SimOrig!INDO-INDO), where

SimOrig!INDO is an original simulation result without the decrement of diesel oil demand and INDO is a new simulation result with 5% decrease.

3.2.2 Price Control

Firstly we set price scenario as shown in Figure 3.2.2 (example). As for gasoline, the price is set as 10 % up. As other fuel price in transportation sector is set to be real constant, price impact is gasoline only.

Figure 3.2.2 Price Scenario

Gasoline		LE/toe	PGASO	=	LAG1.PGASO*1.1
Kerosene		LE/toe	PKERO	=	LAG1.PKERO*(1+INFL/100)
Diesel/Gas Oil for P/P (Boiler)		LE/toe	PDO	=	LAG1.PDO*1.1
Diesel/Gas Oil For Transportation		LE/toe	PDOTR	=	LAG1.PDOTR*(1+INFL/100)
Fuel Oil		LE/toe	PFO	=	LAG1.PFO*(1+INFL/100)
LPG		LE/toe	PLPG	=	LAG1.PLPG*1.1
Natural Gas		LE/toe	PNG	=	LAG1.PNG*(1+INFL/100)
Average		LE/toe	PAVE	=	(PGASO+PKERO+PDOTR+PFO+PLPG+PNG)/6
Coal	(CIF, EU)	US$/ton	PCC	=	LAG1.PCC*(1+INFL/100)

Figure 3.2.3 Model Sheet in Transportation Sector

	(Natural Gas)		ktoe	TRNG	=	0
	Intensity			TRGSI	=	TRGS/GCAR*1000
				TRGSI	$DL,$C	PGASO/CPIU
	Gasoline Demand		ktoe	TRGS	=	TRGSI*GCAR/1000
	Diesel		ktoe	TRDO	$CA	TRFRD+TRFRL
	Jet	(Domestic Air)	ktoe	TRJT	$DL,$C	TRFAR+TRPAR/20
	Fuel Oil		ktoe	TRFO	$CA	ln(TREND)
	Non-Specified		ktoe	TRNS	$TG	
	Lubricant for Transportation		ktoe	TRLB	$CA	TRFRD+TRPRD/20
Petroleum Products Total			ktoe	TRPT	=	TRGS+TRDO+TRJT+TRFO+TRNS+TF

1981	2005	$Y+(SimOrig!TRPT-TRPT)	
1981	1996		
1985	1996		
1982	1996	$Y*(1-.00)^(trend-18)	
1981	1996		
1981	1996		
1992	1998		
1989	1998		
1982	1996		
1981	1998		

Figure 3.2.3 shows a part of model structure and the column AE in transportation sector. Gasoline demand decrease comparing with original simulation of real price constant and shift the difference of original result and new result to natural gas. In this example, natural gas demand is represented as $Y+(SimOrig!TRPT-TRPT), which is same $Y+(SimOrig!TRGS-TRGS), because other fuel demand except gasoline do not change.

APPENDIX (Base of Model Building)

1. General

1.1 Role of Energy Models

Energy models have various objectives such as energy development plan, energy conservation plan, and environmental protection. The results of models can establish scientific basis for comprehensive energy planning and enhance the technical capabilities of national energy use. Models linked to "Energy Balance Table" are also to help preparing available reporting system for policy making in energy sector.

A comprehensive energy database (time series Energy Balance Table) can contribute to foster the common understanding between various energy planning and implementing agencies, and plays an important role for the decision of energy policy. Forecasting energy demand is requisite for stable energy supply and for determining energy supply structure in order to achieve the best mix of energy. Table 1.1 shows the examples of energy model (sub-model) and the objectives.

Table 1.1 Examples of Energy Model (sub-model)

Model	Objective	Contribute to
Energy price model	Demand fluctuation	Price (or tax) policy
Electricity demand forecast	Long-term demand	Power development plan
Macro economic model	Economic growth rate	Economic scenario
Energy conservation	Energy saving potential	Energy saving policy
Oil products price	Demand fluctuation	Price (or tax) policy
Energy export model	National benefit maximum	Export structure

1.2 General Approaches for Model Building

The model is required to be easy in operation and to be transparent and flexible in understanding the methodology and the logic employed. The model also should be built on a flexible system so that the user can revise the data and the model based on annual or quarterly additional data and changes of specific requirements from Government energy policy.

Speaking of energy demand forecasting methods in general, there are two different approaches. One is a process-engineering method (a kind of bottom-up system), while the other is an econometric method. Naturally each has its own advantages and disadvantages.

Regarding data collection as an example, the former involves a wide variety of data, but few time-series data. In contrast, the latter requires few data of this kind but time-series data in the long run (ten years or longer).

The results of the engineering approach are easily understood, since it will provide huge data and explanation. In case of an econometric method, however, the background of forecast results can hardly be explained in detail because macro economic/social indicators are incorporated as exogenous variables. With recognition of these merits and demerits, we are usually applying the econometric approach and combination of both concepts using energy intensities and efficiencies excluding intentional judgment for setting the parameters.

The characteristics of both approaches are completely different from viewpoints of several categories, such as, data collection, handling, scientific points, and results. Typical functional formula of both approaches can expressed as described below.

(1) Process Engineering Approach by Stock Type Demand Function

Demand = SUM (Ei) = Si · Qi · Ri , i =1, n

Ei = energy consumption of i – equipment
Si = energy consuming equipment stock
Qi = equipment efficiency
Ri = equipment operating rate

Taking electricity consumption in residential sector as an example, S represents the number of equipment such as refrigerator, air conditioner, lighting fixture, television, electric cooker, vacuum cleaner, electric carpet and so on. Q represents the efficiency of equipment and R represents using time of equipment. S (equipment stock), Q (efficiency) and R (availability) each has its own function that is determined from the following functional formula, for instant;

$$S_t = S_{t-1} + I_t - S_{t-1} \cdot \gamma$$
$$I_t = f(P_{it}, P_{et}, Y_t, S_{t-1})$$
$$Q_t = f(P_{et}, Q_{t-1}, T_t)$$
$$R_t = f(P_{et}, R_{t-1})$$

Where, S_{t-1} is the number of stock in previous year or previous period. I_t is the newly purchased number and $S_{t-1} \cdot \gamma$ is the disposed number. P_{it} ; price of equipment, P_{et} ; price of energy, Y_t ; income, T_t ; time trend

(2) Economic Approach by Regression Analysis

Table 1.2 below shows the typical functional forms written in “Simple-E model sheet” as an example. In the Table, Y (demand) is defined as internal (dependent) valuable, and X or Xi is external (independent) valuable (GNP and price etc.). Table 1.3 also shows typical demand function as an example.

Table 1.2 Typical functional forms written in "Simple-E model sheet

	Internal Y	Option Type	X1	X2	X3	X4
Typical Functional Form						
Y = a + b*X	DEMAND		GNP.R			
Y = a + b*X + c*Y(-1)	DEMAND		GNP.R	lag1.DEMAND		
LN(Y) = a + b*LN(X)	DEMAND	$DL	GNP.R			
LN(Y) = a + b*X	DEMAND	$SL	GNP.R			
Y = a + b*LN(X)	DEMAND		LN(GNP.R)			
LN(Y) = a + b*LN(X) + c*LN(Y(-1))	DEMAND	$DL	GNP.R	lag1.DEMAND		
LN(Y) = a + b*LN(X1) + c*LN(Y(-1)) + d*X2	DEMAND	$DL	GNP.R	lag1.DEMAND	exp(TREND)	
Y = a + b*X1 + c*X2	DEMAND		GNP.R	PRICE		
Y = a + b*X1 + c*X2 + d*Y(-1)	DEMAND		GNP.R	PRICE	lag1.DEMAND	
LN(Y) = a + b*LN(X1) + c*LN(X2)	DEMAND	$DL	GNP.R	PRICE		
LN(Y) = a + b*X1 + c*X2	DEMAND	$SL	GNP.R	PRICE		
Y = a + b*LN(X1) + c*LN(X2)	DEMAND		LN(GNP.R)	LN(PRICE)		
Y = a + b*LN(X1) + c*X2	DEMAND		LN(GNP.R)	PRICE		
LN(Y) = a + b*LN(X1) + c*LN(X2) + d*LN(Y(-1))	DEMAND	$DL	GNP.R	PRICE	lag1.DEMAND	
LN(Y) = a + b*LN(X1) + c*LN(X2) + d*LN(Y(-1)) + e*X3	DEMAND	$DL	GNP.R	PRICE	lag1.DEMAND	exp(TREND)

Table 1.3 Example of typical flow type demand function

LOG (D) = a + b· LOG(Y) - c· LOG(P) + d· LOG(D(-1)) + e· Time

Y = Income Index

P = Price Index

D(-1) = Demand for previous year

b = Income elasticity (short period)

c = Price elasticity (short period)

1-d=Time adjustment term

e = Technical improvement term

b/(1-d) = Long term Income elasticity

c/(1-d) = Long term Price elasticity

2. Concept of Model Building

2.1 General Items necessary for Energy Model Analysis

2.1.1 Linkage between Macro-economic and Energy Models

In energy supply-demand forecasting, prices of primary energy such as crude oil and LNG are the most important assumed values. As these values in the future are considered to have uncertainty and/or massive fluctuation, it is popular to set some scenario (plural number of cases). Fluctuations of crude oil prices etc. not only have price effects that directly affect energy demand, but produce not a little impacts on the levels of economic/industrial activities, general commodity prices, and secondary energy. It is crucially important to try to make these conditions coherent and integrated their direct/indirect ripple effects into the analysis.

In general, energy demand can be described as a function of income and price.

E = f (I, PE) - (1)

Where, E: Energy Demand
I: Income (Production), + factor
PE: Energy Price, - factor

This means that increased income (production) level pushes energy demand up, while increased price pushes it down. In this point, however, it must be taken into account that income is also a function of energy price with its impact being rather greater than price effect in Equation (1).

I = f (PE, Z) - (2)

Where, Z: Other factors, in addition, Z = f (PE, …)

Hence, energy model's Equation (1) alone is insufficient for making an econometric analysis on relationship between energy price fluctuation and energy demand, and it is essential to grasp more comprehensive data including Equation (2). To say more, structural changes in income/production Ii as well as those in production activity like heavier weight held by services and higher added value-orientation forms crucial factor to determine energy demand as well. Various secondary energy prices and crude oil price can never be independent of general commodity prices, either. Their relative prices pose essential factors in considering inter-energy competition.

2.1.2 Characteristics of Energy Demand

1) Energy itself can never be counted as demand. Namely energy demand is always linked with other inputs to produce satisfactory services (derivative demand). An analysis focusing on use-by-use demand is important.

2) While serving as final goods directly in use at household for instant, energy concurrently is consumed as intermediate goods to enable economic activity.

Energy intensity-based approach
Energy consumption = energy intensity * output

3) Energy demand depends on stock levels of durable goods (energy-consuming appliances) and their utilization factor.

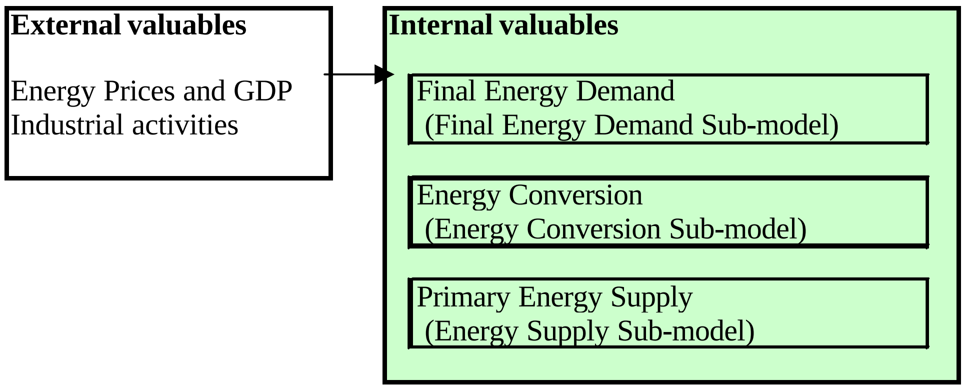
Stock-based approach
Energy demand = technical coefficient * working ratio * capital stock
(gasoline) (fuel consumption) (km) (no. of cars)

Ultimately, the factors described above can be taken as a function of price and income.

2.2 Framework of Energy Demand Forecasting Model

In general, the energy demand-forecasting model consists of final energy demand block, energy conversion block and energy supply block as shown in Figure 2.1. Total flow of energy from final demand to the primary energy supply is determined in the energy balance table. In this model, however, policy factors such as production of crude oil & natural gas, and electricity power development will be handled as exogenous (external) variables.

Figure 2.1 Schematic Diagram of Energy Demand Forecasting Model



Final energy demand block comprising of each sector creates structural equation by energy carrier such as electricity, natural gas and petroleum products (kerosene, LPG, gasoline, diesel oil, fuel oil etc.) and calculates fuel total and sector total. The demand function is estimated by regression analysis in each energy demand for agriculture, mining, manufacturing, transportation, residential/commercial, government/public utilities and non-energy sectors. The final energy demand total is obtained by adding the sector demand.

2.3 Basic Idea for Model Building

The energy demand in each sector is classified into the electric power and non-electric power (fuels), which are estimated by regression analysis. As for fuel demand, two options are taken into consideration; estimation by regression of each fuel and one by use of the fuel source mix calculated by the introduction of the share function. General idea for energy demand forecasting model building can be expressed as follows.

E = EL + F

Where: Final Energy Demand Total — $E = \sum Ei$

Electric Power Demand Total — $EL = \sum ELi$

Fuel Demand Total — $FU = \sum\sum FUij$

i: i sector (i industry)

j: j fuel (oil, coal, and gas, etc.)

Above equations show that the final energy consumption is the sum of power and fuels from the standpoint of energy sources, and corresponds to the total demand of all sectors. Total electric power demand and total fuel demand are obtained respectively by adding up each demand sector. The separation of electric power and fuels is based on the assumption that significant substitution is not performed between electric power and other energy sources.

In regression analysis applied for the estimate of energy demand, energy intensity is used as much as possible. Electric power demand equation and fuel demand equation described below mean that the sectoral demand is a multiplication of the energy intensity and the economic activity level in each sector. In general, these intensities are estimated by regression analysis, and the indicators of economic activities are given as exogenous values in the macroeconomic model.

$ELi = ai*Yi$
$Fi = bi*Yi$

$ai = ELi / Yi$. (ai: electricity intensity to activity level (Yi))
$bi = Fi / Yi$ (bi: fuel intensity to activity level (Yi))

In the case of using intensities, the energy demand is calculated by using the equation below.
$E = \sum (ai*Yi) + \sum (bi*Yi)$

In the case of using share function, the share of the individual energy source is distributed to petroleum products, gas, coal, etc. That is, model takes into consideration of the substitution and the competition of energies, and each share is explained by the relative prices between different energy products, for instant.
Fij (fuel j) $= Fi*Sij$
Where: Sij: Share of each energy source
$Sij = f (Peij / Pei)$
Pe: Energy price

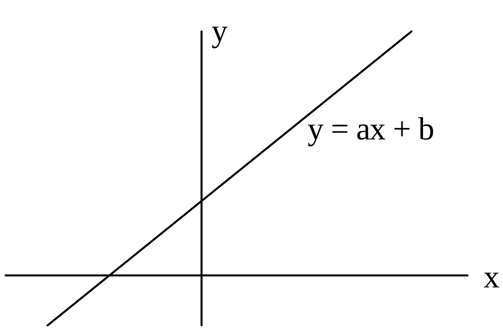
Finally, the primary energy demand is calculated by use of the conversion factor. The conversion efficiency usually improves with technological improvements, especially with new equipment. The time trend and real energy prices become explanatory variables to represent the technological improvement.

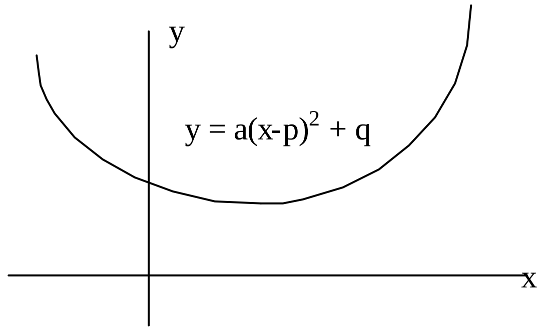
$PER = EL/\alpha + Fj/\beta j$
Where: PER: Primary Energy Requirement (demand)
α and βj : each conversion factor
$\alpha = f (T, Pe)$
$\beta = f (T, Pe)$
T: Time trend

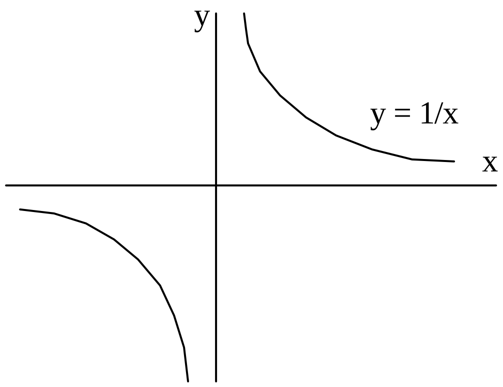
3. Determination of Demand Function

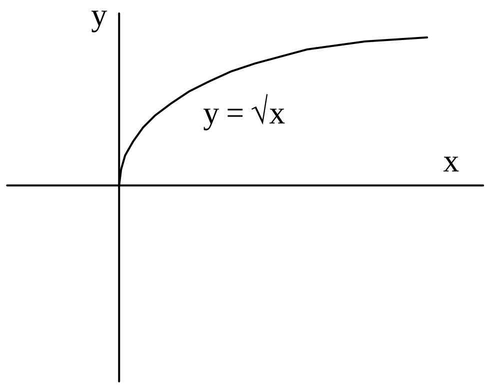
3.1 General functional forms

1) Linear function	$y = ax + b$
2) Quadric function	$y = a(x-p)^2 + q$
3) Fractional function	$y = 1/x$
4) Irrational function	$y = \sqrt{x}$
5) Power function	$y = x^a$
6) Exponential function	$y = a^x$
7) Logarithmic function	$y = \log_a x$ (a=e, natural logarithm)



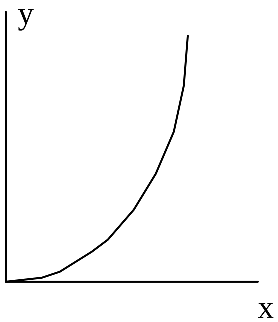


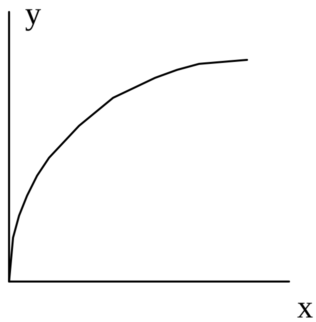


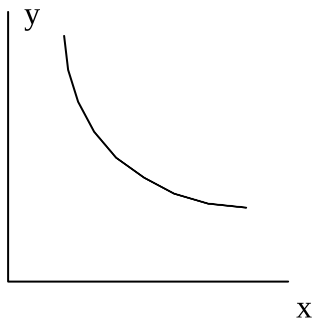


Power function $y = x^a$

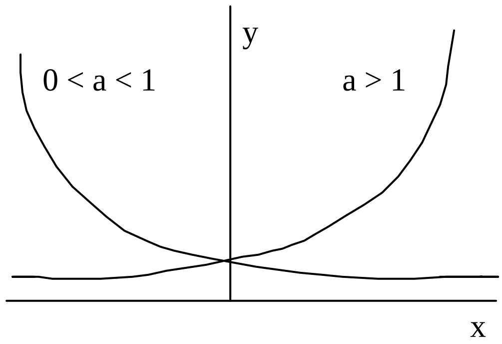
(1) $a > 1$ (2) $1 > a > 0$ (3) $a < 1$



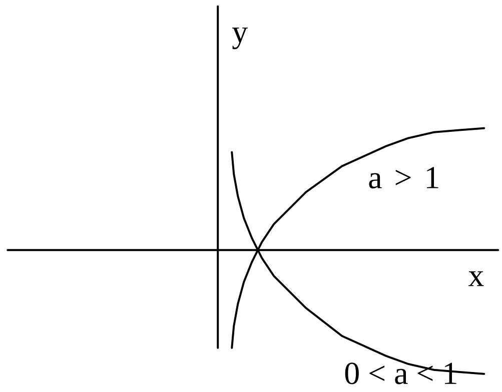




Exponential function $y = a^x$ $(a > 0)$

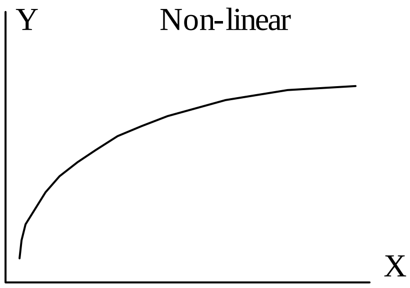


Logarithmic function $y = \log_a x$

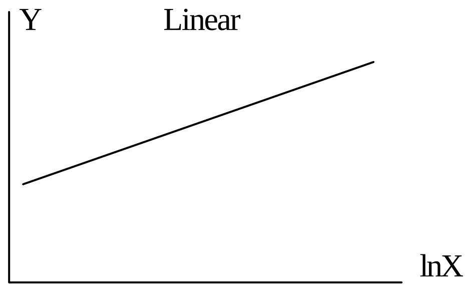


3.3 Linearization

Non-linear	Transformation	Linear	Constraints
1) $y = ax^b$	Y = log y, X = log x	Y = a' + bX	x > 0, y > 0, a > 0
2) $y = e^{a+bx}$	Y = log y	Y = a + bx	y > 0
3) $y = e^{a+bx} / (1 + e^{a+bx})$	Y = log (y / (1 - y))	Y = a + bx	0 < y < 1



Linear-log functional form



Graph of Y against lnX

3.4 Summary of functional forms

Model	Form	Slope	Elasticity	Ave.
Linear	Y=a+b*X	b	b*(X/Y)	Y/X
Double-log	LnY=a+b*LnX	b*(Y/X)	b	Y/X
Linear-log	Y=a+b*LnX	b*(1/X)	b*(1/Y)	Y/X
Log-linear	LnY=a+b*X	b*Y	b*X	Y/X
Reciprocal	Y=a+b*(1/X)	$-b*(1/X^2)$	-b*(1/XY)	Y/X
Logarithmic reciprocal	LnY=a+b*(1/X)	-b*(1/X2)*Y	-b*(1/X)	Y/X
Quadratic	$Y=a+b*X+c*X^2$	b+2*c*X	(b+2*c*X)*(X/Y)	Y/X
Polynomial	$Y=a+b_1X+b_2X^2+b_3X^3 +.....+b_kX^k$	$b_1+2*b_2*X+ .....k*b_kX^{k-1}$	$(b_1+2*b_2*X+.......k*b_kX^{k-1})*(X/Y)$	Y/X
Interaction	Y=a+b*X+c*XZ	b+c*Z	(b+c*Z)*(X/Y)	Y/X
Logistic	Ln(Y/(1-Y))=a+b*X	b*Y*(1-Y)	b*(1-Y)*X	Y/X

Slope (Marginal Propensity) = dY/dX,

Elasticity = (dY/dX)*(X/Y),

Ave. (Average Propensity)= Y/X

3.5 Fitness of Equation by Regression Analysis

1) R — R-Square, $0 \leq$ Explained variance / Total variance ≤ 1, (The larger the better)

2) AR — Adjusted R-Square, $AR \leq 1$, (The larger the better)

3) SD — $SD = (\sum e^2 /(n-k))^{1/2}$,
e = Residual, n = Sample size, k = No. of independent variables

4) DW — Durbin Watoson Statistics, $1 < DW < 3$

- DW = **2** : No serial correlation
- $DW \rightarrow 0$: Positive correlation
- $DW \rightarrow 4$: Negative correlation

5) Dh — Duebin h Statistics with lag, $|Dh| < 2$

6) t-value

- $|$ **t** $|$ ³ **2** : Significant
- $2 > |t| \geq 1$: Admissible to use
- $|t| < 1$: Insignificant

7) Rho — Coefficient of serial correlation, $|Rho| < 1$

8) DF — Degree of Freedom, $DF > 1$ (The lager the better)

9) F — F-Statistics, $F > 0$ (The larger the better)

10) RSS — Residual Sum of Square, $RSS > 0$ (The smaller the better)

11) YX — Correlation Coefficient between Y and X's, $|YX| < 1$

12) XX — Correlation Coefficient between X's, $|XX| < 0.95$

3.6 Dummy Valuables

1) To neglect abnormal value of designated years

Y = a + b*X + c*dum.1991 (observation year 1978-1998)

In 1991, dummy = 1, Y = (a + c) + b*X

Others, dummy = 0, Y = a + b*X

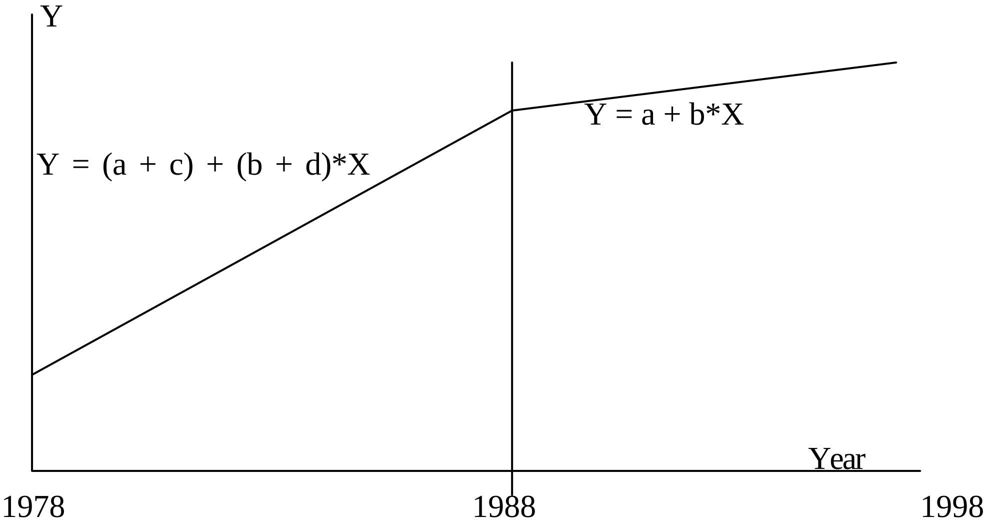
2) To consider structure change of demand function

Y = a + b*X + c*dum.1978..1988 + d* dum.1978..1988 *X

(observation year 1978-1998)

1978-1988, dummy = 1, Y = (a + c) + (b + d)*X

1988-1998, dummy = 0, Y = a + b*X



4. Elasticity and Intensity

Various energy indicators are usually used for energy demand forecasting and supply analysis. Typically two indicators, that is, elasticity and intensity, help us easily understand the relationship between energy and economy.

4.1 Energy Demand Elasticity

Typical energy demand function is determined by income and price as same as other commodities in general. Therefore Demand (D) is function of Income (I) and Price (P).

$$D = f(I, P)$$

$$D = a \cdot I^{b} \cdot P^{c}$$

Taking logarithm of both sides,

$$Ln(D) = a + b \cdot Ln(I) + c \cdot Ln(P)$$

And by partial differentiation,

$$dD/D = b \cdot (dI/I) + c \cdot (dP/P)$$

Where, coefficient b and c mean income elasticity and price elasticity respectively.

$$b = (dD/D) / (dI/I), \quad c = (dD/D) / (dP/P)$$

In order to understand easily, taking assumption that price index (P) is nearly constant,

$$D = a \cdot I^{b}, \ Ln(D) = a + b \cdot Ln(I)$$

Taking differentiation,

$$dD/D = b \cdot (dI/I)$$

$$b = (dD/D) / (dI/I) = ((D(t)-D(t-1)) / D(t-1)) / ((I(t)-I(t-1)) / I(t-1))$$

In this case, the above elasticity is called "gross elasticity" because price is not taken into consideration. In reality, energy demand is not determined by income alone, but depends also on price fluctuations and technological innovations. Nevertheless, this value is generally used because of long-term stability and its easiness in calculating, which is defined as coefficient b of above equation. If we use GDP as an income index, energy elasticity with respect to GDP is also defined as the ratio of growth rate (%) of energy consumption to that (%) of GDP.

Definition $e = (dE/E) / (dGDP/GDP)$ = Growth rate of Energy (%) / Growth rate of GDP (%) where, e = elasticity with respect GDP E = energy demand GDP = Gross Domestic Product

4.2 General Description of Functional Forms and Elasticity

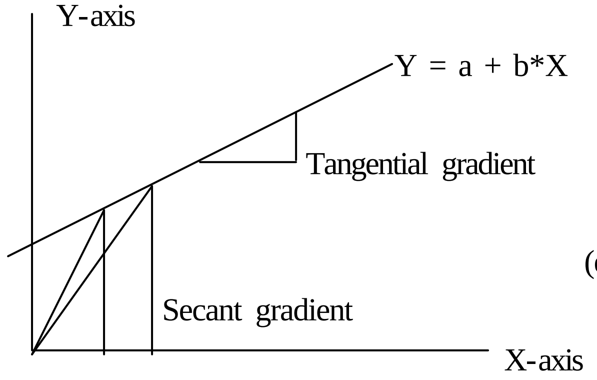
Definition of Elasticity (e)
$Y = f(X)$
$e = (dY/Y) / (dX/X) = (dY/dX) * (X/Y)$

1) $Y = a + b \cdot X$

$dY/dX = b$

$e = (dY/dX) \cdot (X/Y) = b \cdot (X/Y)$,

e(elasticity) is an increase function of X/Y (share of X with respect to Y)



Elasticity e = b*(X/Y)

b = Tangential gradient

Y/X = Secant gradient

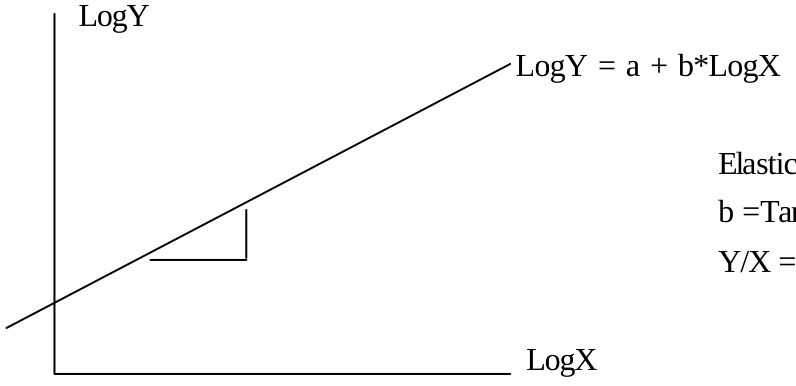
(e = increased function of X/Y)

2) **$\log Y = a + b \cdot \log X$**

$dY/Y = b \cdot (dX/X)$,

$e = (dY/dX) \cdot (X/Y) = b$

b : elasticity



Elasticity e = b (constant)

b =Tangential gradient

Y/X = Secant gradient

3) $\log Y = a + b \cdot X$

$dY/Y = b \cdot dX$,

$e = (dY/dX) \cdot (X/Y) = b \cdot Y \cdot (X/Y) = b \cdot X$

e is an increase function of X

4) $Y = a + b \cdot \log X$

$dY = b \cdot (dX/X)$,

$e = (dY/dX) \cdot (X/Y) = b \cdot (1/X) \cdot (X/Y) = b/Y$

e is a decrease function of Y

5) $\text{Log}Y = a + b \cdot \text{Log}X + c \cdot Z \cdot \text{Log}X$

$dY/Y = b \cdot (dX/X) + c \cdot Z \cdot (dX/X) = (b + c \cdot Z) \cdot (dX/X)$,

$e = (dY/dX) \cdot (X/Y) = b + c \cdot Z$

6) Long-term elasticity and Short-term elasticity (Functional Foam with lag)

6.1) $Y = a + b*X + c*Y(-1)$

In long term, $Y = Y(-1)$, assumption in equilibrium condition

$(1-c)*Y = a + b*X$

$Y = a/(1-c) + b/(1-c)*X$

6.2) $\text{Log}Y = a + b*\text{Log}X + c*\log Y(-1)$

In long term, $Y = Y(-1)$, assumption in equilibrium condition

$\text{Log}Y = a/(1-c) + b/(1-c)*\text{Log}X$

Boundary condition $c = 0$, $\text{Log}Y = a + b*\text{Log}X$

b = Short-term elasticity, $b/(1-c)$ = Long-term elasticity

$1-c$ = Time adjustment term, $0 \leq c < 1$

6.3) $\text{Log}Y = a + b*\text{Log}X1 + c*\log X2 + d*\log Y(-1)$

Same above

b and c = Short-term elasticity,

$b/(1-d)$ and $c/(1-d)$ = Long-term elasticity

$1-d$ = Time adjustment term, $0 \leq d < 1$

Long-term elasticity	$b = b / (1-d)$, $c = c / (1-d)$
Short-term elasticity	b and c

4.3 Energy Demand Intensity

Energy intensity is useful for international comparisons and for observing the status of energy conservation. Although the indicator was originally used for engineering, if the reciprocal is taken, energy consumption/GDP can be interpreted to indicate macro energy productivity.

Energy intensity is broadly used, for example, to show per GDP energy intensity (taking GDP as the denominator) and to show per capita energy intensity (taking population as the denominator). By using various indicators as the denominator, we can introduce various energy intensities for model building.

1) Industrial sector

Intensity (i, j) = amount of energy consumption (i, j) / amount of production (i, j)

Where: i = type of business.

j = energy source (fuels and electricity)

2) Residential and commercial sector

Intensity (j) = amount of energy consumption (j) / household (residential)

Intensity (j) = amount of energy consumption (j) / floor space (commercial)

Where: j = energy source (fuels and electricity)

3) Transportation sector

Intensity (passenger) = amount of energy consumption (j) / person-km

Intensity (freight) = amount of energy consumption (j) / ton-km

Where: j = energy source (fuels and electricity)

5. Examples of Energy Elasticity and Intensities

5.1 Elasticity

Table A.1 shows various values (elasticity) in selected economies and regions. As described before, b-value represents the relationship between energy consumption and economic activity at macroscopic viewpoint.

Regardless of primary energy, electricity or petroleum products, developing economies in Asia marked much higher records than the industrialized countries and regions. It means, in order to achieve a high economic growth, developing countries have consumed more energy than the rest of the world (which is natural for any emerging economies on the way of a takeoff). In addition, GDP elasticity has a tendency to decrease with advancing of economy and shifting of economic and energy supply/demand structure. Electricity consumption and its' per capita consumption represent economic size and economic level in macro standpoint of view. As a reference, we can show typical examples in Asia.

Table A.1 Some Examples of Energy Elasticity

	Elasticity with respect to GDP						Electricity/capita to GDP/capita	
	Primary Energy		Oil		Electricity			
	1985/73	1996/85	1985/73	1996/85	1985/73	1996/85	1985/73	1996/85
North America	0.15	0.71	-0.42	0.47	1.21	1.23	1.39	1.40
OECD Europe	0.39	0.50	-0.88	0.54	1.47	0.93	1.62	0.91
Middle East	5.73	2.23	4.87	1.54	7.32	3.11	-6.29	-3.21
OECD Total	0.32	0.73	-0.44	0.68	1.25	1.16	1.39	1.23
Non-OECD Total	1.13	0.79	-0.57	0.51	1.62	1.47	2.29	3.14
Asia								
Japan	0.31	0.99	-0.52	0.89	0.92	1.23	0.90	1.26
Taiwan	0.96	0.87	0.54	0.85	1.12	1.05	1.15	1.05
South Korea	0.97	1.22	0.70	1.49	1.47	1.50	1.55	1.56
Singapore	0.80	1.28	0.80	1.20	1.24	1.00	1.31	1.00
Indonesia	1.47	1.14	0.97	0.81	2.03	1.79	2.36	2.03
Malaysia	1.55	1.15	1.01	0.92	1.53	1.57	1.77	1.83
Philippines	1.03	1.81	-0.68	2.37	1.77	1.21	4.13	1.68
Thailand	0.84	1.38	0.37	1.34	1.68	1.40	1.96	1.47
India	1.29	1.12	1.17	1.08	1.84	1.39	2.46	1.58
Vietnam		1.45		1.68	1.78	1.72	2.44	2.08

Table A.2 Historical Trends of Electricity Elasticity

Economy	Industrial structure	Period	GWh-GDP	GWh/capita-GDP/capita
South Korea	Heavy-chemical industry oriented (1996, population: 45.5 million, nominal GDP: 485 billion US$)	1962-73 1973-85 1985-96	2.27 1.47 1.50	2.76 1.55 1.56
Taiwan	Light industry oriented (1996, population: 21.5 million, nominal GDP: 273 billion US$)	1952-73 1973-85 1985-95	1.57 1.12 1.05	1.88 1.15 1.05
Japan	(1996, population: 126 million, nominal GDP: 4600 billion US$)	1946-65 1965-73 1973-85 1985-96	1.22 1.29 0.92 1.23	1.26 1.33 0.96 1.26

5.2 Electricity intensity in Japan

Refinery	36 kWh/kl
Cement	110 kWh/ton
Ammonia	485 kWh/ton
BF pig iron	34 kWh/ton
Electric pig iron	750 kWh/ton
BOF steel ingots	43 kWh/ton
Electric-furnace steel ingots	485 kWh/ton

Crude steel total	187 kWh/ton
Hot-rolled steel products	192 kWh/ton
Machine-made paper	771 kWh/ton
Paperboard	490 kWh/ton
Pulp	787 kWh/ton
Alumni	405 kWh/ton
Ethylene	2105 kWh/ton

5.3 Price Elasticity and Income Elasticity

<Example 1>

Estimating income elasticity and price elasticity of primary energy consumption (Ep) and electricity consumption (Ee), the following results were obtained by regression analysis. In this case, real GDP is applied as income index. And also average retail price of coal (Pc, real value) and average electricity tariff (Pe, real value) were used as energy prices respectively. Figures in ( ) mean t-values in formulas below.

Primary energy consumption

$$Ln(Ep) = 1.4375 + 0.334\,Ln(GDP) - 0.0404\,Ln(Pc) + 0.5004\,Ln(Ep(-1))$$

(2.88) (2.77) (-1.04) (3.09)

R-Squared = 0.985

Durbin-Watoson Ratio = 2.314

Electricity consumption

$$Ln(Ee) = 0.0316 + 0.2644\,Ln(GDP) - 0.1309\,Ln(Pe) + 0.8149\,Ln(Ep(-1))$$

(0.205) (1.75) (-1.69) (5.497)

R-Squared = 0.996

Durbin-Watoson Ratio = 1.408

According to above equations, short-term and long-term elasticity of primary energy consumption and electricity consumption with respect GDP are as follows.

	Short-term elasticity		Long- term elasticity	
	to GDP	to Price	to GDP	to Price
Primary energy consumption	0.334	-0.040	0.669	-0.081
Electricity consumption	0.264	-0.131	1.428	-0.707

<Example-2>

Japanese energy demand can be expressed by regression analysis (least square's method) as follow.

LOG (D) = 0.6088+0.1424· LOG (GDP)–0.0523· LOG(Poil/WPI)+0.8085· LOG(D(-1))
t-value (1.17) (3.02) (-3.56) (12.60)
Observation period; 1966-1994
R-Square (R^2) = 0.981
Standard deviation (SD) = 0.03
Durbin-Watoson ratio (WB) = 2.277

Where, D, Poil, WPI, and D(-1) represent the domestic primary energy demand, crude oil price (CIF), wholesales price index, and energy demand in previous year. It shows that short-term price elasticity of Japanese energy demand is small (-0.05) comparing with long-term elasticity (0.27). Income elasticity is 0.14 for the short-term and 0.73 for the long-term.

6. Identification of Problem by Simplified Model

A country is heavily dependent on imported energy resources. It is vulnerable to sudden changes in international energy prices and unstable energy supply. The problem may be solved if the dependency on imported energy is decreased as long as sustainable economic growth is maintained.

1) Basic elements related to a country's energy issue are set as follows.

Gross Domestic Product	GDP	(Ex)
General Price Level	P	
Final Energy Demand	FNED	
Primary Energy Demand	PRED	
Primary Domestic Energy Production	PDEP	(Po)
Energy Import	IMPT	
Energy Intensity to GDP	FNED/GDP	
International Oil Price	POIL	(Ex)
Exchange Rate	EXR	(Ex)
Primary Energy Price (Domestic)	PEP	
Final Energy Price (Domestic)	FEP	
Energy Consumption Tax	TAX	(Po)
Time Trend	TIME	

Where, (Ex): Exogenous variables, (Po): Policy variables

2) Functional forms by regression analyses

LOG (PRED) = 1.897 + 0.876*LOG (FNED) + 0.002*TIME

LOG (FNED/GDP) = 0.933 - 0.115*LOG (FEP/P) – 0.008*TIME
+ 0.709*LOG (FNED(-1)/GDP(-1))

LOG (FEP) = 0.223 + 0.251*LOG (PEP) + 0.814*LOG (TAX)

PEP = 91.04 + 6.276*POIL*EXR

P = 28.355 + 2.983*TIME + 0.308*(PEP/1000)

IMPT = PRED – PDEP

3) Scenario

Exogenous variables

GDP : 4 % growth rate per year

EXR : fixed

POIL : 2 % growth per year

Evaluation -1

Policy variables PDEP : 1 % growth per year TAX : remains as the same level Results PRED : grows at 1 .98 % per year (GDP elasticity = 1.98/4 = 0.50) IMPT : grows at 2.17 % per year IMPT/PRED : increase The amount of energy imports and energy import dependency rate increase.

Evaluation -2

Policy change-1 : Increase tax, TAX : 5 % growth per year Results PRED : grows at 0.97 % per year (GDP elasticity = 0.25) IMPT : grows at 0.96 % per year IMPT/PRED : remains at the same level

Evaluation-3

Policy change-2 : Increase domestic energy production, PDEP : 3 % growth per year Results PRED : same as the first case IMPT : grows at 1.76 % per year IMPT/PRED : declines slightly