PART 3

THEORY AND METHODOLOGY

I. Utilization of EMP Model

The purpose of this paper is to reveal the capabilities and limitations of EMP Model, and to present some ideas to fully utilize it.

Utilizing the full capability in the right way, means in the same time, knowing the limitations and complementing them by the outside informations. It is also required that the works are well organized for the purpose, as for the organization of working group, the schedule of works, etc.

1. General Features of the Model

This model is a LP model which determines the optimal energy supply structure through minimizing total cost of energy supply in this country. When total demands or demands by type of energy for each end use sector and supply prices (costs) for primary energies are given, the model minimizes the total supply cost which is composed of investment costs, variable costs and fixed costs for all sectors.

At first, we will list common natures or limitations of such kind of model. They are due to the logics or simplifications inevitably accompanied with it.

i). For simplicity, the model does not contain all process and their costs in actual economy. For example in this model, traditional energy is treated only simply. And also investment costs are usually narrowly defined (for example, excluding investment cost of offsite facilities for oil refinery).

2). The model affords only optimized results so to say optimal plans in the viewpoint of minimization of total supply cost. We cannot get any optimal plans in the other viewpoints (for example maximization of economic growth, minimization of import of energy, etc.). Moreover, the results cannot be understood as forecasts which mean the (most) probable figures in the future.

3). Performance of the model depends largely on exogenous factors such as end use energy demand, primary energy supply costs, parameters (for costs, capacities, reserves, etc.). To get reasonable results from the model, these inputs data must be carefully prepared. Especially, constraints on capacities affect the performance of the model. The interpretation of results sometimes depends largely on the exogenous factors not on the logics of the model.

Setting aside these common features, we ought to move on in details of the specific feature of EMP Model.

As for the structure of the model, following features can be listed.

1). Effects of energy prices on end use energy demands are only partially explained by this model. For each sector, usually production or some alternative variable and energy intensities by type of energy determines energy demands by type by sector as exogenous variables. And in this process energy prices have no influences.

2). As for investment cost there are some limitations.

- A fixed value is set for investment costs for one type of unit or process. This means that the model cannot take into consideration the difference among investment costs (per unit of capacity) for expansion of existing units and for implanting new units, and also the difference among different scales of units.
- This model cannot determine optimal investment (incremental capacity) as discrete volumes, as in the actual situation where capacity increases discontineously unit by unit. Accordingly in interpreting the results about capacity increases, we must convert them to values actually possible as a sum of discrete units.
- This model does not take into account sunk costs (investment costs which have already been invested at the starting year of runs). This may cause some distortions in the results from the real optimality.

3). Space dimension is not considered in this model. Various costs, especially transportation costs, change according to the spatial factors. The model cannot optimize the results taking into consideration these spatial factors.

However, in interpreting the results, considerations on these factors are required. For example, for the electricity sector, capacity increases by type of plant implicitly their locations in limited number (for lignite-fired plant, at Mae Moe or Krabi). It must be checked if some increase of capacity changes regional supply-demand balance and increases implicit transportation costs among regions.

On the performance of the model, two problems are presented here.

1). Shadow prices can be useful for analysis only in limited fields.

- Every step of energy flows from primary energy to end-use energy is open to import. So shadow prices are usually affected by import prices. Adding to this, the portions of endogenous cost which accompany with domestic activities in price is small, and has small influence on (shadow) prices of energy. By these reasons, shadow prices are determined largely by extraction costs of indigenous energy and import prices of primary and secondary energy, in spite of constraints set on capacities. Consequently, shadow prices have small implications in the analysis on endogenous factors (especially policies on investments) of the model.

2). The performance of the model is not sensitive to changes of exogenous variables (for example, energy prices). This is because for end-use energy, energy prices are not inputted in the linkage equations, and substitution possibilities among types of energy built in the model are very limitted (probably reflecting the actual situations). And also because, for energy sector, although the sensibilities are formally large, they are limitted by constraints to produce plausible results considering practical policies, limitations on sites or supply capacities of primary energy, etc.

2. Capability and Limitation by Block of the Model

1). End-use Energy Demand

In the present model, total end-use energy demands (and some demands by type of energy) by sector are determined exogenously, and the compositions of demand by type determined by the model are not sensitive to price changes. The method of calculating the total demands by using the linkage equations and energy intensities is not effective enough to provide realistic and persuasive forecasts. So the figures for end-use energy demands should be considered as assumptions.

To make them more reliable for analysis, much more informations and logics besides the methodologies in the model are required.

Two ways can be considered for improving them.

- Improving this part of the model by inputting prices as explanatory variables in the linkage equations, or moreover modifying it by building small scale models for each sector.
- Using another model, for example Energy Price Model, for this part. End-use energy demand by type and by sector determined by this model can be used for EMP Model, or only macro-economic variables and prices determined by Energy Price Model may be used for the linkage equations.

By these two methods, we may be able to get more reliable estimates for end-use energy demands, taking into consideration the relations among energy demands, energy prices and macro-economic variables.

Besides the problems for the whole model, some specific problems can be presented. For example, traditional energy is treated independently without considering the substitutions to the other energies. Energy consumptions in the transportation sector are determined only by the activities (or total numbers of vehicles by type), efficiencies by type of fuel and constraints on the possibilities of substitution between fuels, without considering number of vehicles by type of fuel consumed and other technological factors. For the electricity demands, load factors are only simply considered, spatial factors which are important for this sector are almost neglected.

2). <u>Energy Sectors</u>

Two major endogenous energy sectors in this model are the electricity sector and the oil refinery sector. For these two sectors, the model determines the optimal fuel uses or feedstock inputs and the optimal capacity increases for types of unit reflecting shadow prices of fuels and feedstocks. The other energy sectors, i.e. natural gas, lignite, coal etc., are rather exogenous, and capacities for some processes mainly for transportation in those sectors are determined by the model.

(1). Electricity sector

The model determines the optimal capacity increases by type of unit by peak or base load, based on generation costs, taking into consideration load factors by voltage.

This sector is one of the key sectors in the model. It determines the optimal capacity increases within a wide range of possibility of substitution among the types of unit. And, it is the sole major consumer of some types of energy, i.e. lignite, coal and natural gas. It has large influences on the supply-demand conditions of indigenous energies and consequently on the shadow prices of these energies.

The analyses on the shadow prices of fuels for electricity generation may provide useful informations about the comparative costs of types of primary energy in the domestic market, especially competitiveness of indigenous energies to imported energies.

It can also determine shadow prices of electricity for medium voltage consumers and low voltage consumers by demand categories (summer, winter, peak load, and base load). However, the results should be carefully interpreted becasue of the limitations mentioned above (neglect of spatial factors etc.).

(2). Oil refinery sector

For this sector, in determining the optimal capacity increases, imports of crude and petroleum products play a important role, along with the refining costs for types of unit. This sector has formally a large range of optimization because the model can substitute increase of import of petroluem products to capacity increases, if the former is cheaper than the latter.

However, because of the limitations mentioned above (neglect of the difference of investment costs caused by the nature of increase of capacity) and the difficulty of estimating accurate costs, we cannot rely so much on this part of the model. In operating the model the constraints on capacities in this sector should be narrowly set based on outside informations mentioned below, so that they will not provide unrealistic results.

The optimality about the capacity increases can be more directly evaluated by the world market condition of petroleum products. If the surplus of refinery capacity in the world is forecasted to remain for long-term, it is better for this country to utilize it and to import petroleum products not increasing refinery capacity.

The constraints on refinery capacities should be set based on these informations.

Accordingly the shadow prices of petroleum products are not useful informations for the analysis on the pricing policy for them. Becuase as their shadow prices are determined by the international prices (import prices, or in some case export prices) or refining costs which are also related to international prices, actually they will become close to their international prices in the long-run. In other words, the model optimizes the results assuming that the retail prices are set close to the international prices.

(3). Natural gas sector

The model determines capacity increases for some processing and transportation facilities based on extraction costs, supply capacities for various fields. This sector has relatively simple structure and is mainly composed of transportation. By these reasons, the optimality of capacity increase depends substantially on the extraction costs (purchasing prices from the concessionaires for extraction) and deliverabilities of the fields. For this sector, the effectiveness of results of runs is affected by how much the exogenous factors, such as the relation between extraction costs and deliverabilities, are analysed befores the runs.

(4). The other modern energy

For coal and lignite, the model has only small endogenous activities. They can be considered almost exogenous.

(5). Traditional energy

For traditional energy, the extraction costs are neglected in the model, and the activities existing up to the end use, for example transportation, are also almost neglected.

In relation to this, substitution between traditional and modern energy is not considered in this model (except the electricity sector).

3. Utilization of the Model

1). Purpose of Works

Policy on energy supply must be planned taking into consideration not only the factors proper to the energy supply sectors but also all factors which have interrelations with the energy sectors. On the other hand, the model covers only very narrow range of the factors needed for the planning. Consequently, to utilize the model for planning, the informations and logics or theories outside the model are required.

A brief list of the factors concerning energy supply policy can be presented below. Here, (A) means factors endogenously treated in the model, (B) : exogenous factors, (C) : factors not treated explicitly.

(1). International Conditions

- Imported energy prices (B)

(2). Domestic Macro-Economic Variables

- GDP (B)
- Industrial structure (B)
- Public finance (C)
- Balance of payment (C)

(3). Demand of energy

- Energy demand by sector (B)
- Substitution and conservation (A), (B) or (C)

(4). Supply of energy

- Capacities (investments) and supply costs of processes by sector (A)
- Reserves (supply capacity) and extraction costs for primary energies by sector (B)

(5). Prices of energy

- Wholesale and retail prices (C)
- Shadow prices (opportunity costs) (A)

Policy objectives to be considered may be as follows :

(1). Economic growth (B)

(2). Policy objectives in the viewpoint of equity or distribution (promotion of modern energy consumption in the household sector, rural electrification). (C)

(3). Minimizing energy supply cost (A)

(4). Reduction of energy consumption (energy conservation) (B)

(5). Reduction of energy import (A)

Planning must be conducted in the whole framework which interrelate the all factors above. The model can determine only the capacities by energy supply sector (and imports of energy) by the logic of minimizing total energy supply cost, subject to the other factors given exogenously.

To get persuasive and practical plans, users of the model must always consider the factors outside the model in relation with endogenous factors, especially interpreting results of the model.

The users must know : (1) the interrelations among these exogenous factors and policy issues, (2) the meanings or functions of values actually given to exogenous variables. And scenarios for runs of the model must be set so that they are actually probable and useful for the analyses on actual situations.

2). Scenario Setting

There are two types of factor by which scenarios are composed. The first are factors which determines energy demand and supply conditions from outside of the model, such as macro-economic performance of the economy (growth rates of GDP and it's components) and import prices and domestic supply prices (costs) of energy. The second are factors (parameters, etc.) inside the model which determine the structure and performance of the energy demand-supply system of this country.

The table shows principal factors for setting scenarios. The first group of factors performs overall influences on the system through various causal relations but the second group (excluding objective functions) is a specific factor which influences directly only on a part of the system.

Combining these factors, various scenarios can be developed. Following the mothodology in the EMP reports, Base Case should be set as "the most likely" combination of exogenous variables, which will provide the most probable results.

The alternative scenarios are developed by changing some factors in Base Case as shown in the table.

Factors for Setting Scenarios

Factors	Base Case	Alternatives
Out of the model GDP growth rate	NESDB's forecast	high, low
Energy import prices	based on the World Bank's forecast	high, low
Structure of the model Supply side Available gas reserve	most likely	decreased
Electricity generating capacity	not constrained	policy target (promotion of some types of plant)
Refining capacity	policy target, most likely	increased
Miscellaneous (nuclear, domestic crude, etc.)	most likely	(nuclear energy promoted)
Demand side Fuel substitution (in transport)	most likely	policy target
Electric power requirement of rural households	most likely	promotion of rural electrification
Load factor of electricity demand	most likely	low load factor
Efficiency of consumption	no improvement	improved
Economywide Import of energy (foreign exchange)	optimization results	policy target (minimum import)
Objective function	total investment	alternative discount rate

3). <u>Organization of the Project</u>

As I have no conviction about my understanding on the present situation of this project, I present here some impressions and personal opinions based on my experience. This is a "if in Japan" story.

(1). Organization of the staff

There is no need to add anything to the description in the EMP reports, as for the staffs required for the project. The working group should be consisted of a few economists, engineers and staffs trained in computer programming, and is now composed actually like this. They are enough capable.

As for the management, I would like to add some opinions of mine.

Informations and theories owned by all staffs are required to be well organized and utilized in every step of the works, i.e., developing secenarios, analysing results and writing reports. Because it may be difficult for any one person to understand the all informations concerned in and out of the model, to overlook the whole works and write the whole report.

For this, all staffs must be informed, at least, outlines of the whole work. Communications among the staffs should be promoted. Periodically meetings of all participants are held.

(2). Procedure of works

The following procedure can be presented as an example.

- Making exogenous variables and parameters, and developing scenarios

For making or up-dating exogenous variables and setting contraints on them, the capabilities of staffs should be fully utilized. Roughly speaking, the works require mainly following specialities by each.

Macro-economic variables	economics
Energy prices	economics
Linkage equations	economics
End-use energy intensity by sector	engineering
Parameters (for market allocation, costs etc.)	engineering
Constraints on capacities	informations on the actual situation

One or a few staffs take responsibility for some part of these works respectively. They will collect all informations related their works and analyse them, and also be required to be responsible about their results.

In developing scenarios, the precise consideration on the concerned factors and on the directions of effects on all factors by changing some factors are required.

The works in this step have large influences on the usefulness of the results of runs conducted in the works at the next step.

- Analyses on the results and writing report

The results must be analysed in the whole framework discussed above.

As the first step, the results should be checked and analysed partially. And it may be convenient that each staff takes charge of the parts in which he did in preparing the runs. Besides these works, the ananyses on shadow prices and macro-economic analysis (total supply, demand of energy, total investment, total import of energy etc.) must be conducted by some staffs. They should participate in writing report about their works in this steps (at least, draft report or materials for the final report).

The final report may be written by some (3-4) persons including the chief of the project, under a well organized plans prepared through substantial discussions by the participants.

Appendix

A1. Technical Papers

A1.1 On the Revision of Investment Cost Parameters for Refinery Capacity Expansion (Revised)

A1.2 On the Revision of Investment Cost Parameters for Natural Gas Sector

A1.3 Calculation of Shadow Prices and Generating Cost in the Electricity Sector

A1.4 Estimation of Cost Parameters in EMP Model : A Recommendation on the Methodology of Estimation and Calculation

A1.5 Prelimanary Study on the Estimation of Demand Function by Type of Energy

A2. Terms of Reference and Other Documents

A2.1 Terms of Reference for MR. OSAMU KUMAKURA (Expert in Energy Economics and Planning)

A2.2 Memorandum on Terms of Reference for MR. OSAMU KUMAKURA

A2.3 Note on Progress and Proposed Future Plan of Work on the Energy Master Plan Project

A1.1 On the Revision of Investment Cost Parameters for Refinery Capacity Expansion (Revised)

This is an attempt to reviso parameters for investment costs in EMP model. Using published informations about the expansion plan by TORC refinory, a simple methodology of revision will be presented.

1. Capacity expansion of TORC refinery for 1986-1989 is planned as follows:

	Incremental Capacity (BPSD)
Crude unit	18,500
Vacuum unit	32,300
Hydrocracker	17,000
Thermal cracker	6,300

(Foster Wheeler's study (1983) etc.)

Total investment cost including utilities and offsite facilities is estimated to be $525.0 million (nominal price, including tax etc., including escalation of 11%) according to the Foster Wheeler's study (1983), and $700.0 million (nominal price) according to the World Bank's energy assessment report (1985).

2. On the other hand, investment costs by unit for capacity expansion by the same plan can be calculated using the methodology and the estimates of investment cost by the EMP study for the year 1980. Investment cost for capacity expansion of a type

of unit can be estimated based on the investment cost estimates considering the effect on cost by the difference of capacities. By EMP study, the following relation is assumed.

(investment cost for expansion of capacity Y)

$$\approx \left(\frac{Y}{X}\right)^{0.6} \cdot \text{(investment cost for expansion of capacity X)}$$

Using this equation, investment costs by type of unit are estimated as follows :

	Investment cost estimated based on the EMP estimates (1980 price) (million $US)
Crude unit	13.3
Vacuum unit	14.3
Hydrocracker	67.6
Thermal cracker	7.1
Offsite facilities	29.2
Total	131.5

(Cost for offsite facilities are assumed to be proportional to the scale of crude unit same as the EMP estimates)

3. Total investment cost $700.0 at nominal price is converted to one at 1985 price by the following method.

$700.0 is assumed to be allocated to four years from 1986 to 1991 (the first row) following the World Bank's report(P.213). These values are

	1986	1987	1988	1989	Total
nominal	$140 million	210	210	140	700
1985 price	126.1	170.4	153.6	92.2	542.3

converted to 1985 prices using escalation rate of 11% (the second row). We can assume that the total cost $542.3 million at 1985 price corresponds to $131.5 million at 1980 price.

We can get investment costs for capacity expansions by type, multipling costs at 1980 by the ratio between total costs at 1985 and at 1980 for each type of unit. Unit costs are calculated from these total costs and heat values of output of each unit.

	Incremental Capacity (BPSD)	Investment cost (million $US)	Unit Cost ($US/TCAY)
Crude unit	18,500	54.8	10,776
Vacuum unit	32,300	59.0	7,259
Hydrocracker	17,040	278.8	143,172
Thermal cracker	6,300	29.3	10,254
Offsite		120.4	
Total		542.3	

Cost for the other units can be estimated multiply the unit costs at 1980 price by the ratio (542.3/131.5 = 4.124).

	Unit Cost ($UA/TCAY)
Catalytic cracking	53,200
Reforming	28,868
Catalytic polymerization	35,879
Del coker	37,941
Solvent deasphalting	8,603

These figures will be used as values of COST-INV for the period 1986-1989. For the period from 1990, the same methodology can be applied using, for example, informations about TORC's provable expansion plan. However, it is acceptable to use the figures for 1986-1989 as ones for 1990-2001.

Parameters COST-INV

	\$US80/TCAY (old)	\$US85/TCAY (new) *)
Crude distillation	420.8	10,776.0
Vacuum distillation	768.7	7,259.0
Catalitic cracking	12,900.0	53,200.0
Thermal cracking	1,700.0	10,254.0
Reforming	7,000.0	28,868.0
Hydrocracking	19,300.0	143,172.0
Catalytic polymerization	8,700.0	35,879.0
Del coker	9,200.0	37,941.0
Solvent deashalting	2,086.0	8,603.0

*) including tax etc.

A1.2 On the Revision of Investment Cost Parameters for Natural Gas Sector*

Estimate of Investment Costs

	Million US$	Capacity
Pipeline from ESSO to Khon Kaen	20 a)	
Pipeline from Texas Pacific to Erawan	303 a)	250 MMcfd
Gas Distribution Pipeline to Industry	42 a)	
Gas Separation Plant	60 a) 320 b)	150 MMcfd 350 MMcfd
Pipeline from Erawan to Khanon	190 b)	60 MMcfd

Data Sources a) : World Bank Energy Assessment Report (1985)

b) : PTT, Annual Report 1984

*) About the methodology of calculation, refer ON THE REVISION OF INVESTMENT COST PARAMETERS FOR REFINERY CAPACITY EXPANSION

Calculation of Real Values

(Million US$)

	1985	1986	1987	1988	1989	1990	1991	Total Cost: Nominal	Total Cost: 1985 Price
Pipeline from ESSO to Khon Kaen			4	10	6			20	
			3.25	7.31	3.95				14.51
Pipeline from Texas Pacific to Erawan					56	150	97	303	
					36.89	98.81	63.9		199.60
Gas Distribution Pipeline to Indus.			12	25	5			42	
			9.74	18.28	3.29				31.31
Gas Separation Plant			12	30	18			60	
			9.74	21.94	11.86				43.54
			64	160	96			320	
			51.94	117.0	63.24				232.18
Pipeline from Erawan to Khonon							190 a)	190	
							101.58		101.58

Escalation 11% per year is used to calculate real value.

Allocation of investment by World Bank Energy Assessment Report except a) with is assumed by the author.

Paramotors COST-INV

	Old Parameter US$/TCAY	Now Parameter US85$/TCAY
Extract ESSO	8,320($U85)	
Extract Texas-B	8,560($U85)	8,680
Separate Overall	7,630($U85)	7,670
		17,532
Extract Khanon	8,560($U85)	18,406
Export Overall	80,450($U80)	
Extract BLK-10	5,653(U$80)	
Extract Compress	4,077($U83)	
Extract Overall	8,560($U85)	
Transport Overall	2,694($U80)	
Transport To-Elec	6,636($U80)	

Heating value 252 Kcal/scf is used.

A1.3 Calculation of Shadow Prices and Generating Cost in the Electricity Sector

1. Calculation of Shadow Prices of Fuel Inputs

(1). Shadow prices (duals) of fuel inputs to electricity sector

	1986	1991	1996	2001
Lignite	7,336	10,550	9,852	3,905
Fuel Oil	6,988	12,410	17,460	6,920
Coal	7,502	10,720	10,760	4,722
Natural Gas	8,372	12,990	14,780	7,258
Heavy Crude	9,228	18,000	16,810	6,664

(2). Shadow prices adjusted by the discount rate* (1986 price)

	1986	1991	1996	2001
Lignite	7,336	18,589	30,600	21,376
Fuel Oil	6,988	12,866	54,231	37,880
Coal	7,502	18,889	33,421	25,848
Natural Gas	8,372	22,889	45,907	39,730
Heavy Crude	9,228	31,716	52,212	36,479

*) The discount rate = 0.12

(1991) = 1.762 x (dual, 1991)

(1996) = 3.106 x (dual, 1996)

(2001) = 5.474 x (dual, 2001)

(3). Shadow prices at 1986 US$/Tcal

	1986	1991	1996	2001
Lignite	7,189	18,589	30,600	21,376
Fuel Oil	6,848	21,866	54,231	37,880
Coal	7,352	18,889	33,421	25,848
Natural Gas	8,204	22,889	45,907	39,730
Import Prices Heavy Crude	9,043	12,532	12,792	13,058
Fuel Oil	6,848	13,303	13,579	13,861
Coal	6,925	7,703	7,222	7,372

*)

$$\frac{\text{Shadow price adjusted of input fuel)}\times\text{(Import price of heavy crude)}}{\text{(Shadow price adjusted of heavy crude)}}$$

2. Calculation of Generating Costs

(1). Formulas

(Generating cost) = (Fuel cost) + (Other costs)

$$(\text{Fuel cost}\ ^{\$/KWH}) = (\text{Dual for fuel}\ ^{\$/Tcal}) \times 860/10^{9} / (\text{GROS-EFF})$$

$$(\text{Otho costs}\ ^{\$/KWH}) = [\ At + (\text{COST-FIX})\ ] / 8760 / (\text{AVAI-FAC}) + (\text{COST-VAR})/10^{6}$$

At (: Annuity of investment cost)

$$= CIt \cdot \left(\frac{(1+a)^{DV} \cdot a}{(1+a)^{DV} - 1} \right)$$

where CIt : Investment cost

DV : Life time of plant

a : Interest rate

(2). Used parameters (86 US$)

	Lignite Fired	Oil-Gas Fired	Coal Fired	Gas Combined Cycle
COST-INV($/KWH)	1,203	1,030	1,051	673
COST-FIX($/KWH)	23.35	11.68	16.06	8.75
COST-VAR($/GWH)	2,481	1.314	1,850	7,058
GROS-EFF	0.32	0.365(g)	0.344	0.38
		0.348(o)		
AVAI-FAC	0.75	0.78	0.77	0.78
LIFE-TFC(years)	25	25	25	25

(3). Generating costs by type of plant

(1986 US$/Kwh)

	1986	1991	1996	2001
Lignite-Fired				
Fuel Cost	0.019	0.020	0.020	0.021
Other Costs	0.029	0.029	0.029	0.029
Total	0.048	0.049	0.049	0.050
Oil-Gas-Fired				
Fuel Cost	0.019 (g) 0.035 (o)	0.021 0.021	0.028 0.033	0.032 0.034
Other Costs	0.018	0.018	0.018	0.018
Total	0.037 (g) 0.035 (o)	0.039 0.039	0.046 0.051	0.050 0.052
Coal-Fired				
Fuel Cost	0.018	0.019	0.020	0.023
Other Costs	0.024	0.024	0.024	0.024
Total	0.042	0.043	0.044	0.047
Gas-Combined Cycle				
Fuel Cost	0.019	0.020	0.025	0.032
Other Costs	0.016	0.016	0.016	0.016
Total	0.035	0.036	0.041	0.048

A1.4 Estimation of Cost Parameters in EMP Model

A Recommendation on

the Methodology of Estimation and Calculation

1. Estimation of Cost

(1) Investment (Construction) cost

a). If estimates of cost for individual projects are available, they can be used.

Data Sources :

- Long-term investment plans, annual reports and other documents by individual companies
- Construction permit application to BOI
- Cost estimates by UNDP/World Bank etc.

Data for gas sector may be obtained mainly from these sources.

b). Estimation based on total or unit cost data from the other sources.

Data Sources :

- Total cost or unit cost in other countries (e.g., construction cost of pipeline, oil and gas journal)
- Cost estimation by EMP project

For oil sector, investment costs may be estimated from these data under some assumptions.

(2) Fixed cost, variable cost

For these cost, any reliable data may not be available. So estimation will be made based on the EMP estimate under some assumption on escalation or technological changes.

2. Calculation of Parameters

The calculation methodology of COST-INV

Step 1 Calculation of total investment cost and capacity (in Tcal) taking into account input structure throughout the simulation period.

Step 2 calculation of COST-INV

Two Examples in EMP Model are shown below.

(1). Natural gas, Union Platform - Rayong

Dimension	34" O.D. (Capacity 750 MMscfd)
Distance	264 miles
Cost per mile	$1.5 million
Total cost	$396 million

(Vol.VI, p31-3)

Capacity per year (in Tcal)

$= 750 \times 10^{6} \times 365 \times 252 \times 10^{3} = 68,985$ (Tcal)

(Natural gas, Erawan 252 Kcal/scf)

COST-INV

$= 396 \times 10^{6} / 68985 = 5740.3$ \$/TCAL (EMP : 5653)

(2). Crude oil

COST-INV's are calculated using the data for the ESSO expansion.

a). Vacuum unit

Capacity	34,000 BCD
Investment cost	$14.8 Million

Capacity per year

$= 34 \times 10^{3} \times 365/6.414 \times 0.01000 = 19,348$ Tcal/year

(Conversion factors for long residue 0.01000 Tcal/T 6.414 B/T)

COST-INV

$= 14.8 \times 10^{6} / 19348 = 764.9$ \$/TCAY (EMP : 768.7)

b). Solvent deasphalting

Capacity 20,000 BCD

Investment cost \$21.6 Million

Capacity per year

$= 20 \times 10^{3} \times 365/6.001 \times 0.01001 = 12.177$ Tcal/Y

COST-INV

$= 21.6 \times 10^{6} /12177 = 1,773.8$ \$/TCAY (EMP : 2086)

c). Crude distillation

Capacity 75,000 BCD (Total)

Investment cost \$16.7 Million

Capacity per year

$= 75 \times 10^{3} \times 365/7.055 \times 0.01012 = 39,267.9$

COST-INV

$= 16.7 \times 10^{6} /39267.9 = 425.3$ \$/TCAY (EMP : 420.8)

A1.5 Prelimanary Study on the Estimation of Demand Function by Type of Energy

I tried to estimate some types of equations which explain effects on energy demand of prices of energy. Some results which are statistically significant are shown as follows :

Period of estimation : 1979 - 1984

Variables

GATL : Total consumption of gasoline (10^6 litres)

DLTL : Total consumption of diesel oil (10^6 litres)

FOTL : Total consumption of fuel oil (10^6 litres)

GATR : Consumption of gasoline by transportation sector (10^6 litres)

DLTR : Consumption of diesel oil by tranportation sector (10^6 litres)

RPGA : Retail prices of gasoline (฿/litres)

RPDL : Retail prices of diesel oil (฿/litres)

RPFO : Retail prices of fuel oil (฿/litres)

Time : Year (1970 = 1)

1). Ratio between consumption of gasoline and that of diesel oil (Total)

$$\ln(GATL/DLTL) = \underset{(0.93)}{0.1295} - \underset{(-1.74)}{0.34951} \cdot \ln(RPGA/RPDL) - 0.05346\ \text{time} \quad \text{---(1)}$$

$\bar{R}^2$ = 0.878 S.D. = 0.04 D.W. = 2.15

2). Ratio between consumption of fuel oil and that of diesel oil (Total)

$$\ln(FOTL/DLTL) = \underset{(0.57)}{0.44938} - \underset{(-1.10)}{1.20176} \cdot \ln(RPFO/RPDL) - \underset{(-2.42)}{0.09023}\ time \qquad ---(2)$$

$\bar{R}^2 = 0.649 \quad S.D. = 0.14 \quad D.W. = 2.02$

3). Ratio between consumption of gasoline and that of diesel oil (Transportation sector)

$$\ln(GATR/DLTR) = \underset{(5.78)}{1.53949} - \underset{(-1.86)}{0.71216} \cdot \ln(RPGA/RPDL) - \underset{(-6.28)}{0.11464}\ time \qquad ---(3)$$

$\bar{R}^2 = 0.901 \quad S.D. = 0.08 \quad D.W. = 2.854$

These results mean that, if relative price of gasoline to diesel oil increases 1%, ratio between consumption of gasoline and that of diesel oil decreases 0.35% in total and 0.71% in transportation sector, and if relative price of fuel oil to diesel oil increases 1%, ratio between consumption of fuel oil and that of diesel oil decrease 1.20% in total.

For other couples of types of energy, no statistically significant equation is estimated.

Calculation of energy demand using these results

1). If total consumption of energy (or that of petroleum products) are given, and if consumptions of other types of energy demand functions of which are not estimated are assumed to be unchanged, we can calculate consumption levels of every energy at given levels of their prices, using the equations.

2). This method is simple, but better than the method such as calculating price elasticity of demand directly from historical data, and applying it to calculate demands.

Calculation of price elasticity of demand

Price elasticity of demand (E) is defined as follows :

$$E = \frac{\partial \ln Xi}{\partial \ln Pj} = \frac{\frac{dXi}{Xi}}{\frac{dPj}{Pj}} = \frac{\frac{(Xit - Xio)}{Xio}}{\frac{(Pjt - Pio)}{Pjo}}$$

where X : demand

P : price

suffix i, j : types of energy

t, o : time

In the equation (1), if DLTL is assumed independent to RPGA, price elasticity of demand for gasoline is -0.35.

Price elasticity calculated directly from historical data is different from that calculated from demand functions.

A2.1 Terms of Reference for MR. OSAMU KUMAKURA

(Expert in Energy Economics and Planning)

1. Objective

Thailand Energy Master Plan (EMP) is used as a tool in providing a long-range, sector wide energy plan for the country. As investment costs for energy development plan require a lot of foreign currency as well as energy import expenditure, it, therefore, is essential to analyze foreign exchange impacts of alternative investment strategies for different energy supplies.

2. Scope of Work

2.1 Review EMP methodology and input data used in the EMP model

2.2 Review the linkage variables between macro-economic model and the EMP model for sectoral energy demand forecasts and analyze in order to develop into appreprïate variables.

2.3 Analyze parameter data on demand side such as industry sector, transportation sector, agriculture sector, household and tertiary sector, particularly, in supply side which is composed of capital cost, non-fuel operating cost, output energy cost. These parameter data need to improve in currently situation.

2.4 To revise a base year (or current) into the year 1984 instead of the year 1982.

2.5 To build alternative scenarios due to energy pricing change, economic growth and undertainty of indegenous energy resources.

2.6 To carry out impact analysis to the economic structure due to the change in alternative scenarios.

2.7 To elaborate and analysis the logic and methodology of developing and adopting various accounting values, shadow prices, interest and discount rates, inflation rates, future price assumptions.

2.8 To formulate a policy guideline and plan implementation.

2.9 To study the liking methodology of Thai input-output (I-O) model with EMP model in order to provide the capability to investigate policy questions as follow :

- The impacts to the economy-wide due to change in energy resources availability, technology improvement etc.
- The guidelines for feedback on energy, projection, and conversion of various non-energy economic policies that may be adopted in the future.

A2.2 Memorandum on Terms of Reference for Mr. O.Kumakura

(February 24, 1986)

For the purpose to achieve my role required by Terms of Reference, I would like to present scope of work in detail and work schedule based on our discussion and study up to the present. The role of the expert is to advise and assist concerning to following works and to achive technical transfer to the counterparts.

1. Scope of Work

Works described in Scope of Work can be grouped into 3 items as follows :

1.1 Up-date and improve EMP models (Scope of Work, 2.1~2.4)

1.2 Make use of the model for analysis on energy problem and energy policy implementation (do, 2.5~2.8)

1.3 Link the Thai input-output model with EMP model (2.9)

1.1 Up-date and improve EMP models

1). Review EMP methodology and input data used in the model (2.1)

a). Analyse the theoretical structure and performance of the model.

b). Review input data and output variables.

c). Study some possibilities of improvement of the model.

2). Review the linkage variables (2.2)

a). Review the linkage block of the model and study methodology of linkage b). Review the figures of end-use energy demand.

c). Study some possibilities of improvement of the model to take into account more explicitly effects of price and income on end-use energy demands.

3). Review parameters on demand side and supply side, and up-date these parameters to current situations (2.3)

Review and up-date the parameters by using published sources and informations from consumers and suppliers of energy.

As for the demand side parameters (volumes and compositions of end-use energy demands), economic method can be mainly applied for forecasting them in the future. But for supply side, technological informations, informations concerning policy and schedule of energy supply (or extraction), etc. are required.

4). Revise the base year (2.4)

a). Up-date parameters to the base year 1984.

b). Analyse some technological problems relating to changing base years.

1.2 Make use of the model for analysis of the energy problem and energy policy implementation.

These works are related with each other, and should be conducted in enough understnading of the structure and performance of the model.

1). Build alternative scenarios (2.5)

Build alternative scenarios, based on various assumptions on energy price changes, economic growth rate and other macro-economic variables and uncertainty of indigenous energy supply etc.

2). Carry out impact analysis (2.6)

Analyse effects on principal objective variables such as foreign exchange, total cost of energy supply, efficiency of energy supply and consumption, etc., comparing simulation results under different scenarios.

3). Elaborate the logic and methodology to interpret and analyse the results in the viewpoint of national energy policy making (2.7)

Organize factors, relating to (1) energy supply and demand, national economic development, (2) objectives and measures of economic and energy policy, and (3) technical or exogenous factors such as reserves of indigenous energy, prices of imported energy. And formulate the methodology to utilize the model, based on the theories and methodologies involved in the EMP model.

4). Present informations useful for national energy policy making, formulate guidelines for policy and plan implementation, such as energy pricing policy, indigenous energy supply policy, allocation of primary energy to conversion sectors and investment policy for energy sectors, etc. (2.8)

1.3 Study the linking methodology of the Thai input-out medel with EMP model. (2.9)

Study the possibility to link these models, and conducts some preliminary works to link. And in the case the work was successful, operate the models for the purpose of analysing the interaction between (non-energy) economic policies and energy policies.

2. Work Shedule

Scope of Work		1986			
		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1.Up-date and improve EMP	1.Review EMP Methodology and input data used in the model	├──┤			
	2.Review the linkage variables	├──┤- - -	- - - -	- - - -	- - - -
	3.Review and update parameters	├──────┤	- - - -	- - - -	- - - -
	4.Revise the base year	├──	───┤		
2.Make use of model	1.Build alternative scenarios	├──────┤	├──	──────┤	
	2.Carry out impact analysis	├──────┤	├──	──────┤	
	3.Elaborate the logic and the methodology to interpret and analyse results	├──────┤	├──	──────┤	
	4.Present informations useful for national energy policy making				├──────┤
3.Study the linking methodology			├──	──────	──────┤

A2.3 Note on Progress and Proposed Future Plan of Work on the Energy Master Plan Project

(January 14, 1987)

As my term was extended six months until June 1987, my work schedule needs to be revised. In this note, hoping that our works become more fruitful, I would like to review our works in the past year and reconsidering the problems, present my opinion about strategies to promote our works, and my work plan in the next six months.

1. Works in the past one year

My (our) works related to the EMP Project in the past one year are as follows :

1). Works proper to the EMP Model

- Grasp the whole structure of the model
- Develop scenarios using alternative forecasts of energy prices.
- Up-date or revise parameters of the model, i.e., capacities of energy sectors, flows of energy, and investment costs.
- Review linkage equations, and attempt to estimate them taking into consideration the effects of prices.
- Interpret and analyse the results of runs, and write some reports on the supply and investment plans in energy sectors.

2). Related works

- Analyses on energy demand in transport and householetertially sectors.

- Analysis on price changes of crude oil and petroleum products.

2. Present stage of EMP project

The present stage of the project can be summerized as follows :

1). Some improvements of the model are needed (for example, for electricity sector). As the informations about the performance of the model have been accumulated, improvement of the model is now easier than before.

2). Some scenarios useful for the analyses are to be developed, based on the experiences by the runs performed in the past.

3). More measures to improve the model are now available than before, by some parameters (by up-dating or by changing based on the outside informations of the model) or changing linkage equations. Some measures should be adopted if they are useful and do not take too much man-hours.

4). Using the results of new runs, writing final report should be started. To do this, a tentative organization of the report should be developed at first.

3. Proposed strategies to promote our works

Reflecting on our works in the past one year, there are some problems which seems to need improvements. In my impression, to promote our works more efficiently, we need to pay more attention to organization of works such as arrangement of steps of works.

1). Proposed strategies

Based on these reflections, the following strategies are proposed ;

- Concentrate on the necessary works to attain the objectives (to develop the energy master plan), and do not stick to works which are not directly necessary for them, and arrange works so that they can be done efficiently.

At this stage, the following works should be done at first.

- Set new scenarios which are useful for the analysis (cf., On the Scenario Setting in the EMP Model), and conduct analysis running the model.
- In parallel with the runs of the model, develop a clear concept for the future energy plan and policy.

2). Methodology (or Approach) to interpret results of runs and to develop energy plan and policy.

- Do not depend too much on the logic of the model, accordingly do not stick to the results of the model. The logic of the model (the minimization of the total investment cost) is only one of the factors which should be considered in planning and policy making. (Sometimes model should be considered only a tool which generate consistent figures in the future.) And the model cannot provide reasonable results without setting constraints based on outside informations.

- Utilize informations outside the model, such as plans or forecasts by the other organizations, informations from past data, etc. And try to interpret the results considering those outside informations by various logics (or viewpoints) not only built in the model but also out of the model such as minimization of total import of energy.
- Develop future prospects of supply and demand of energy and economic development and some other principal factors both in this country and in the world. Analyse causal relations among these factors.
- Establish plans and policies consistent to these prospects and inter-relations of factors.

4. Proposed work plan

Because, the scope of work by the original terms of reference does not need any large modifications or additions, the main part of my work will be composed of the works originally planned and not accomplished yet. The following works will be conducted in the next six months.

1. Up-date and improve the model.

   This work will be done in the early stage of the term and in restricted fields in which some effective works are possible in a short time.

2. Conduct runs of the model for alternative scenarios. And conduct analysis on the optimal investment plan in energy

sector and on the effects on energy supply-demand structure by energy policy, energy prices and macro-economic factors.

3. Write a final report arranging all my works for EMP project, which will be useful to the staffs.

Work Schedule

	1987	
	Jan.- Mar.	Apr.- Jun.
1. Up-dating and improvement of the model	|-------|	
2. Analysis		
On the optimal investment plan	|-----------|	
On the effect by energy policy, prices and macro-economic factors	|----	------|
3. Writing a final report	|----------------	----------------|