Asiam

WG3 Demand Forecast
Material 3

Simple-E Installation and Operation

20~24 December 2021
Asiam Research Institute, Inc.
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Section 1
Installation of the Software

Preparations

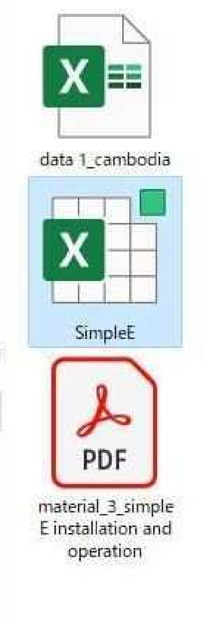
What we need ?

Documents we have send to you.

(1) Software: “SimpleE.xlam”

(2) A excel file: “data 1_cambodia.xlsx”

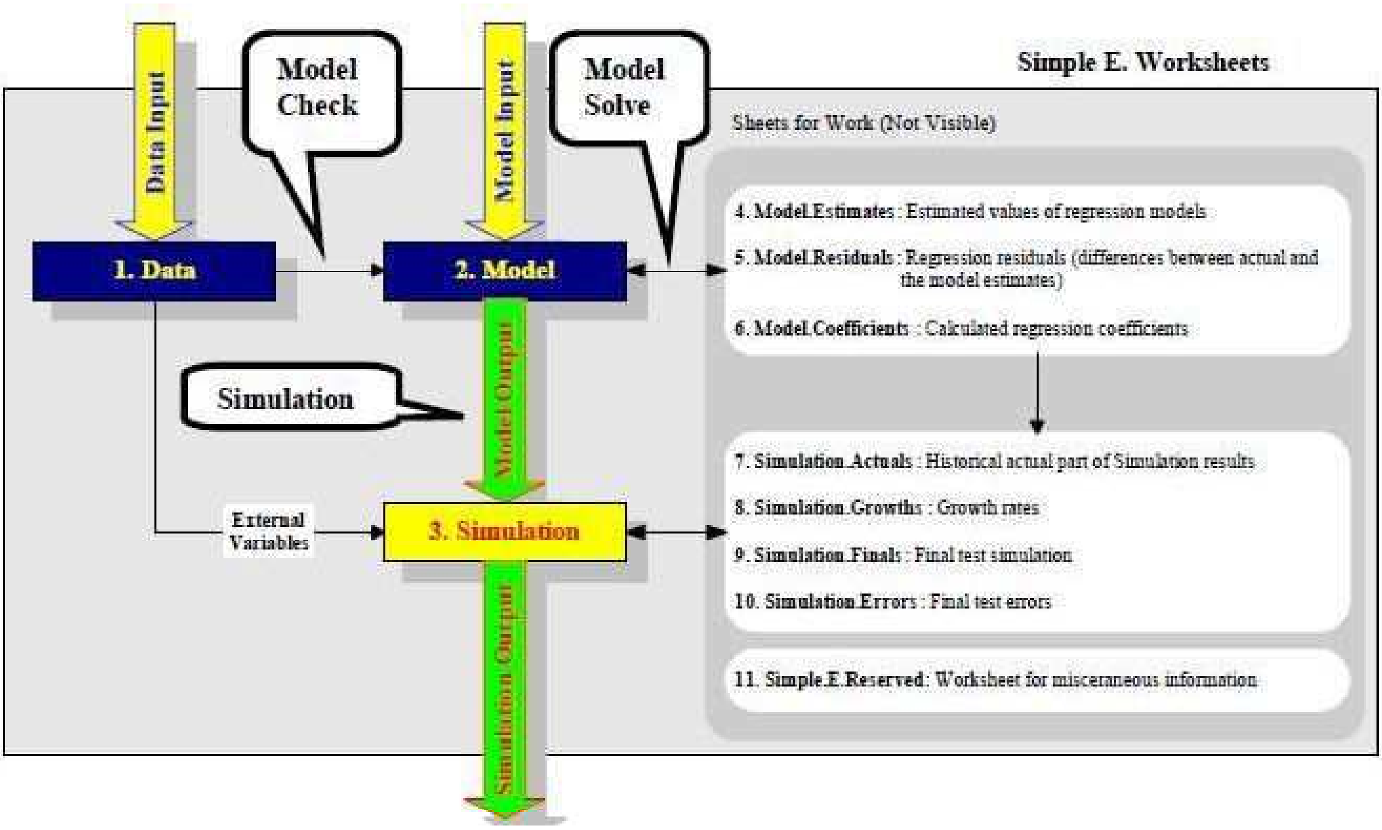
(3) A PDF file:“material_3_simpleE installation and operation.pdf”



Prepare by yourself

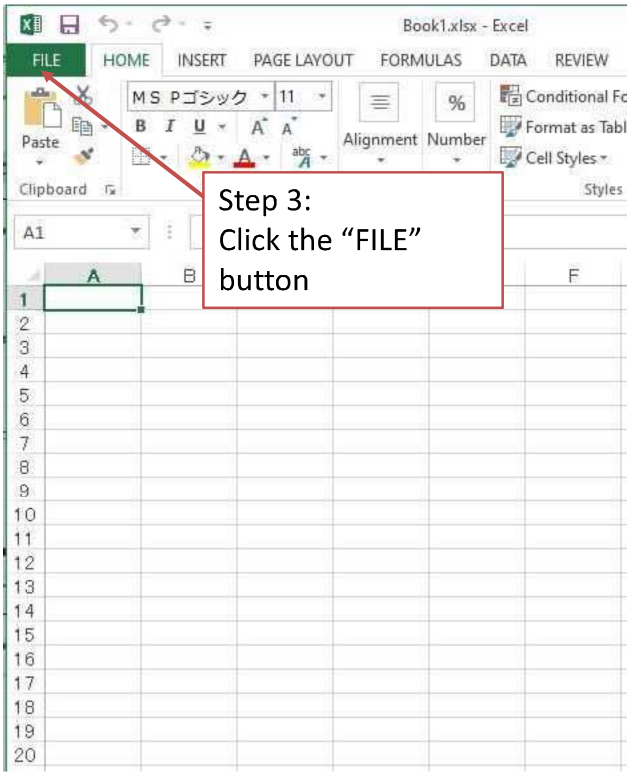
(4) A computer with Microsoft Office “Excel”.

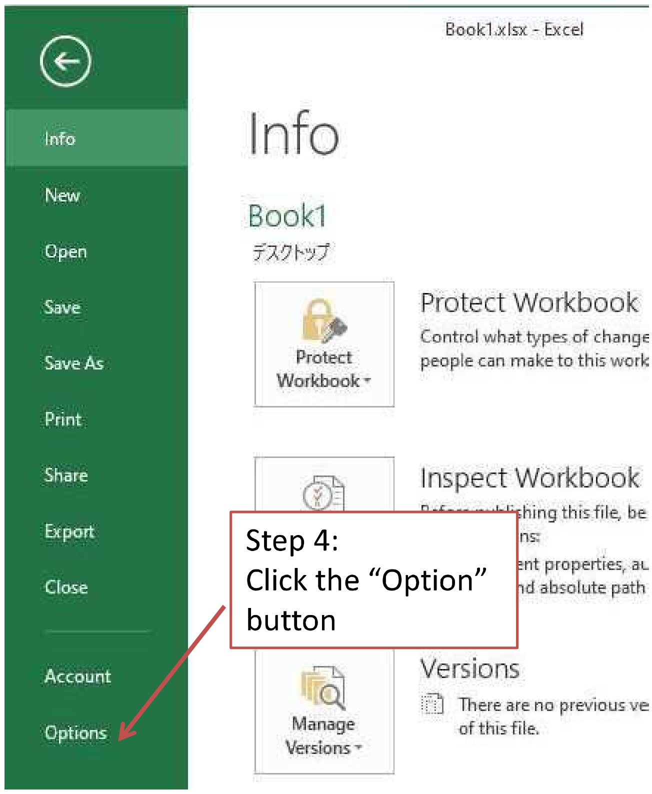
Conceptual Diagram of SEE



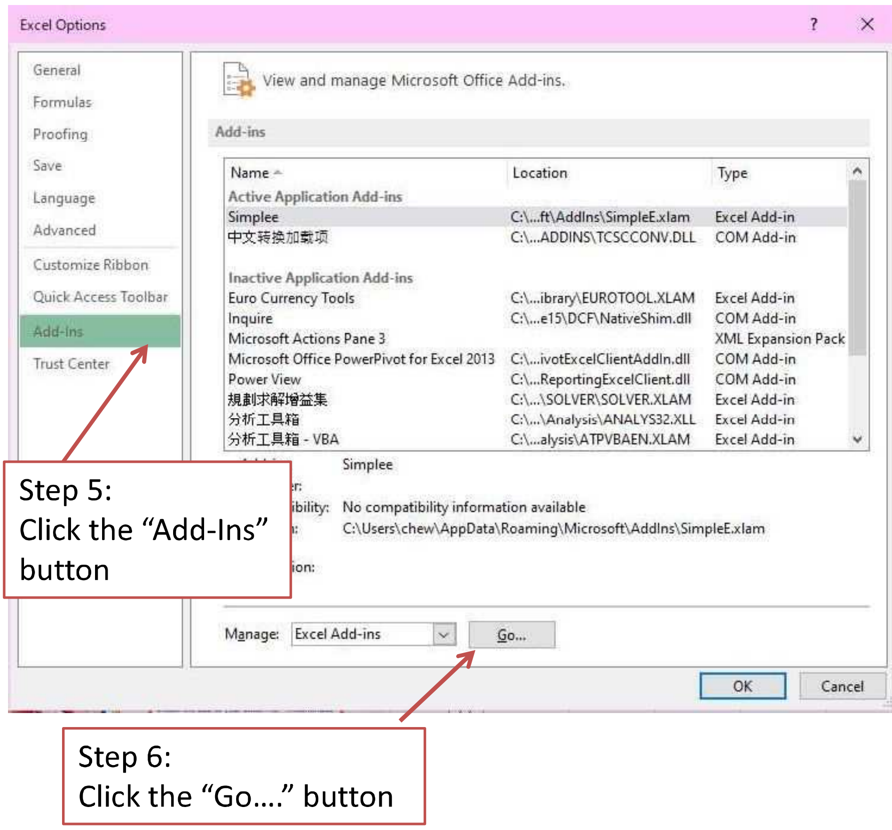
Install the SEE to your Excel File

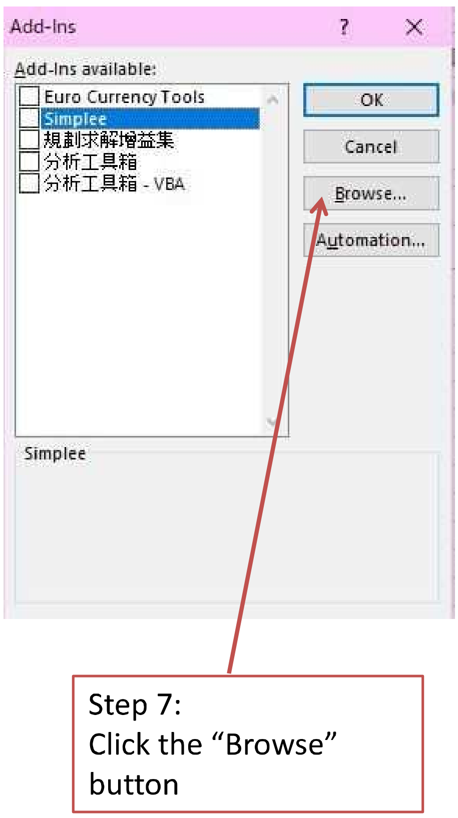
Step1: Copy the “SimpleE.xlam” file to your computer (you can put it on your desktop).
Step2: Open a new “excel ” file.



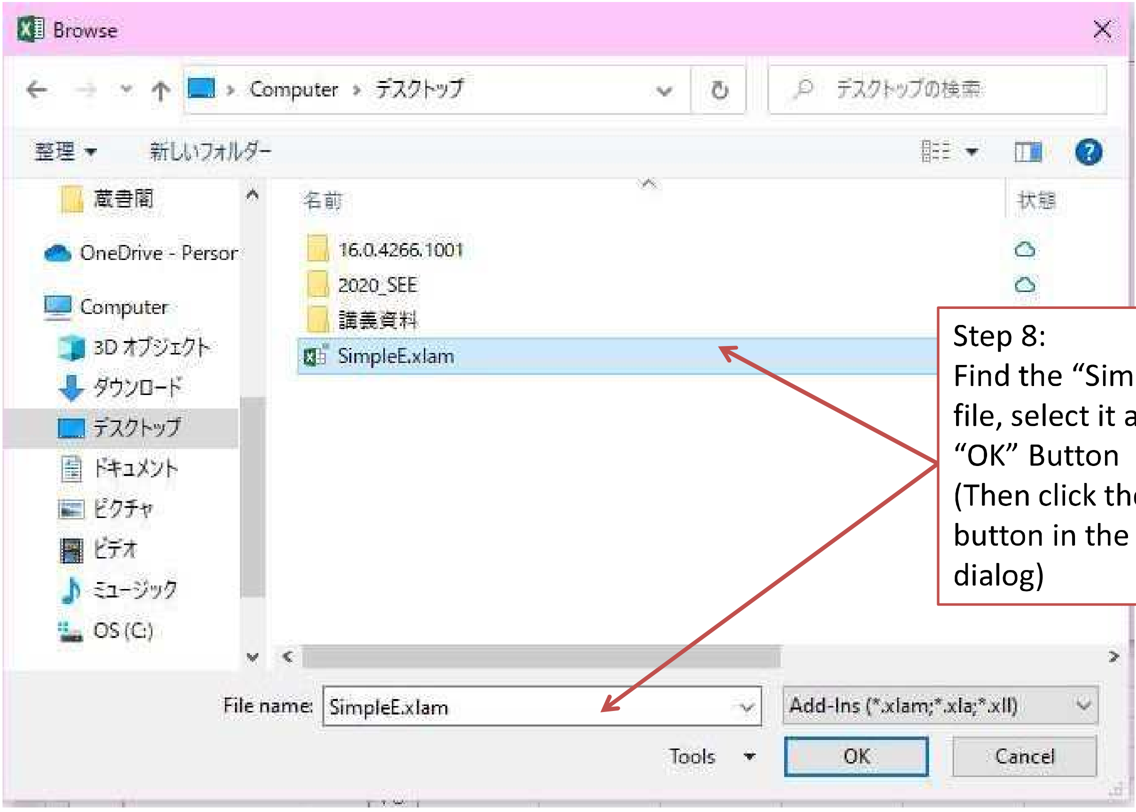


Install the SEE to your Excel File ~....continued





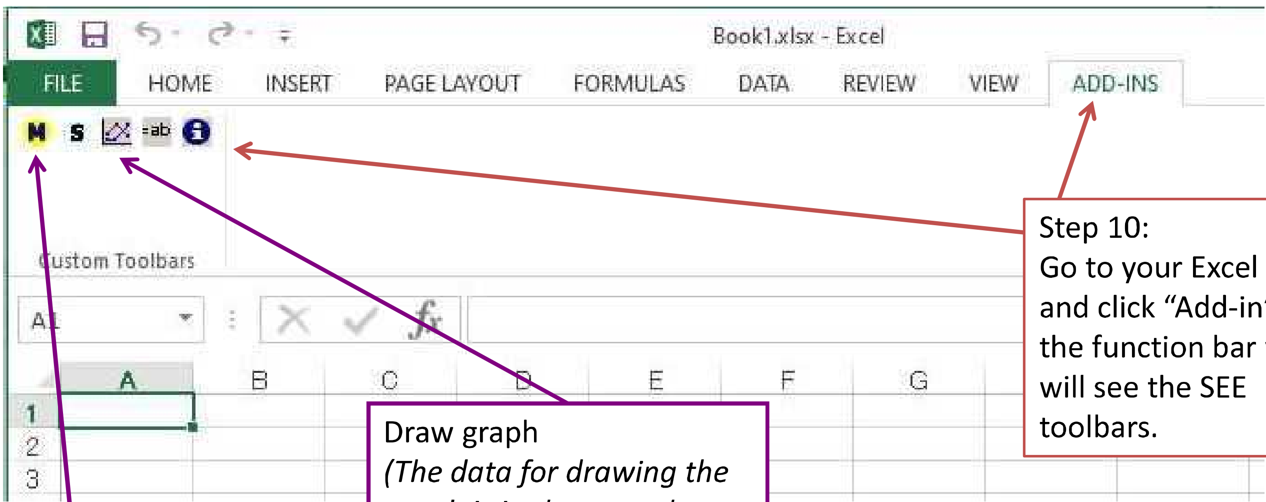
Install the SEE to your Excel File ~….continued



Step 8:
Find the "SimpleE.xlam" file, select it and click "OK" Button
(Then click the "OK" button in the Add-in dialog)

Install the SEE to your Excel File ~….continued

Step9: Close the Excel file and re-open a new Excel file.

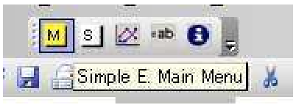


Step 10:
Go to your Excel file and click "Add-in" in the function bar you will see the SEE toolbars.

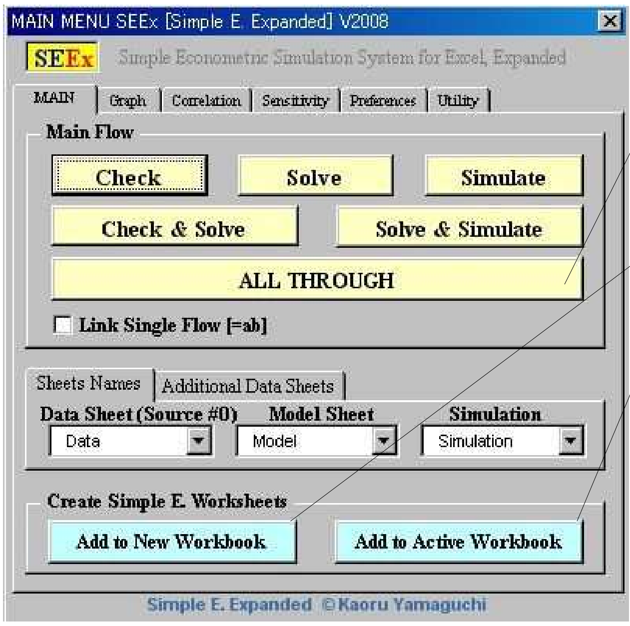
Draw graph
(The data for drawing the graph is in the row where you put you cursor)

Main Menu

Main Menu of the SEE



Button to start the *Main Menu*



Button to start the simulation of the whole model.

Button to create SEE working sheets in a new file .

Button to create SEE working sheets in the current file .

SEE working sheets

Section 2
How to Start Model Building With SEE

Before start SEE, you need to….

(1)Formulation the question of interest

Example: Total Primary Energy Supply (TPES) analysis

(2)Specify variables

TPES is a function of GDP (Real GDP)

$$TPES = f(GDP)$$

$$or\ TPES = a + b \times GDP + u$$

- Result TPES: Dependent variable
- Cause GDP: Independent variable

(3)Collect Data

Source, Period of time, Unit etc.

How to start model building with SEE

- Then with SEE
  - Input the data in the "data sheet"
  - Build your model in the "model sheet "
  - Test the fitness of your estimation by checking the parameters in the "model sheet"
  - The prediction results are given in the "simulation sheet "
- After…
  - You can do any analysis you like with the output data

Practice (file: data_1_Cambodia)

(1)Formulation the question of interest

Total Primary Energy Supply (TPES) analysis of Cambodia

(2)Specify variables

TPES is a function of GDP (Real GDP of Cambodia)

Cambodia TPES = *f* (Cambodia GDP)

*or TPES = a + b * GDP + u*

- **Result** TPES: Dependent variable
- **Cause** GDP: Independent variable

(3)Collect Data

Source, Period of time, Unit etc.

Input data

	Coal	Natural Gas	Crude Oil	LPG	Gasoline	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Naphtha
Production	882	2174	20	0	0	0	0	0	0	0
Imports	3853	0	12738	633	1043	215	36	2330	387	[illegible]
Exports	0	0	0	0	0	0	0	−136	−716	−533
International Marine Bunkers	0	0	0	0	0	0	0	−81	−103	0
Stock Changes	0	0	−116	−5	−2	−1	−4	−43	51	−31
Total Primary Energy Supply	4735	2174								
Statistical Differences	200	0								
Total Transformation Sector	−3864	−2174								
Main Activity Producers Electricity Plant	−3630	−2174								
Autoproducer Electricity Plant	0	0								
Petroleum Refineries	0	0								
Coal Mines	−234	0								
Oil and Gas Extraction	0	0								
Petroleum Refineries	0	0								
Own Use in Electricity, CHP and Heat Plant	0	0								
Distribution Losses	0	0								
Total Final Consumption	1071	0								
Total Industry Sector	932	0								
Iron and Steel	9	0								
Chemical and Petrochemical	18	0								
Non-Metallic Minerals	905	0								
Machinery	0	0								
Mining and Quarrying	0	0								
Food and Tobacco	0	0								
Paper, Pulp and Printing	0	0								
Wood and Wood Products	0	0								
Construction	0	0								
Textile and Leather	0	0								
Non-specified Industry	0	0								
Total Transport Sector	0	0								
International Aviation	0	0								
Domestic Aviation	0	0								
Road	0	0								
Rail	0	0								
Domestic Navigation	0	0								
Total Other Sectors	0	0								
Agriculture	0	0								
Commercial and Public Services	0	0								
Residential	0	0								
Non-specified Other	0	0								
Non-Energy Use	139	0								
Electricity Output in GWh	14517	13141								

C47 fx %

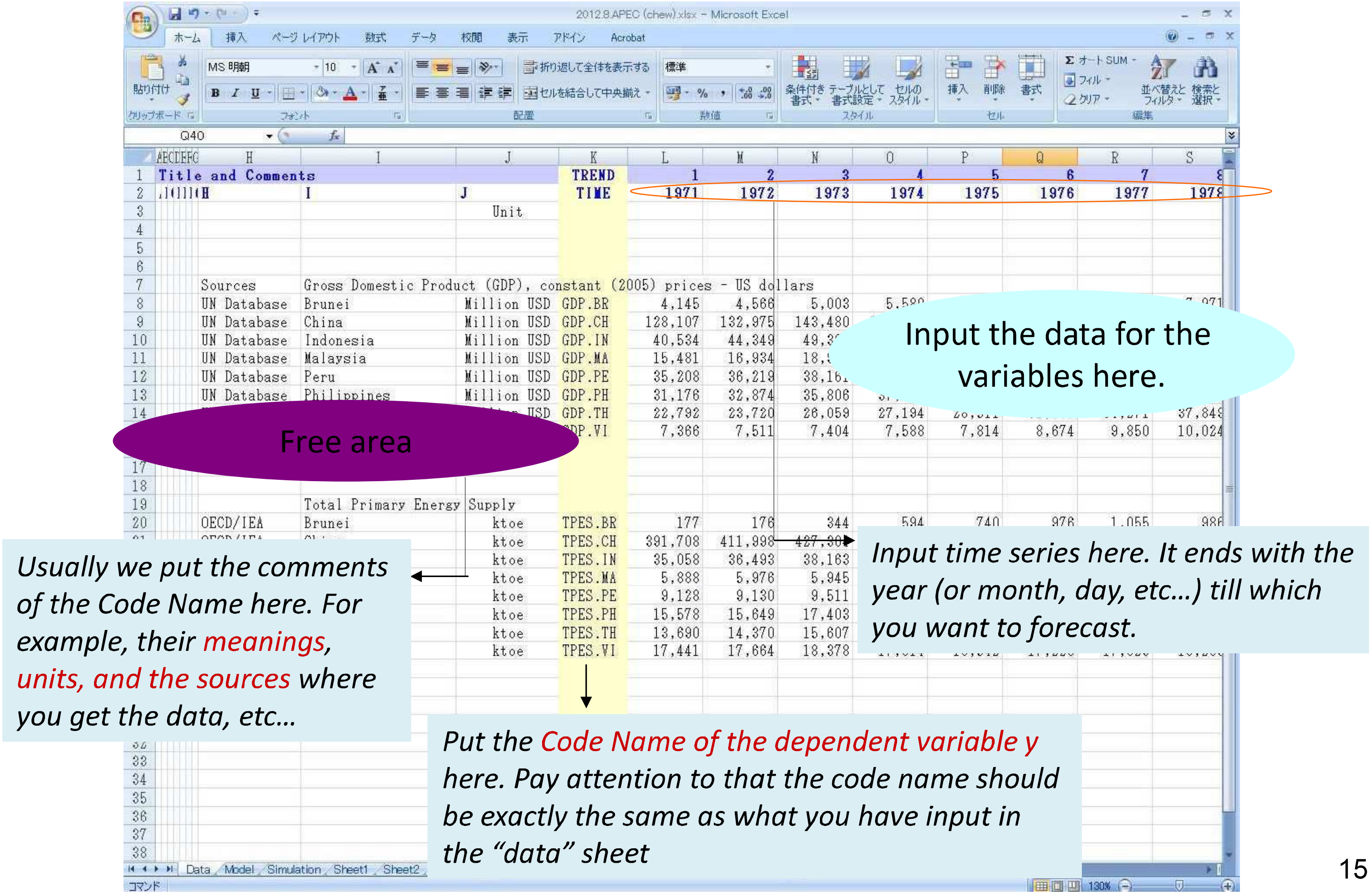
	A	B	C	K	L	M	N	O	P	Q	R	S	T
1	Title and Comments			TREND	1	2	3	4	5	6	7	8	9
2	A	B	C	TIME	1990	1991	1992	1993	1994	1995	1996	1997	1998
3	METI	GDP (Constant 2000 Price)	Billion $	GDP	3,206	3,482	3,749	4,316	4,751	5,005	4,413	4,049	3,824
4	ARI	Annual Groth Rate of GDP	%	GDPR	6	2.3	0.7	-0.5	1.5	1.9	2.6	1.6	-2.0
5	EDMC	Population	Million	POPU	124	124.1	124.6	124.9	125.3	125.6	125.9	126.2	126.5
6	Production index(2005=100)												
7	EDMC	Industry		IPID	100	99.7	93.8	90.4	93.2	95.2	98.4	99.5	92.7
8	EDMC	Commercial		IPCM	84	86.6	86.1	87.0	88.6	90.7	93.0	92.6	92.7
9	Electricity Consumption												
10	IEA	Total final consumption	TWh	ELTL	769	795	800	810	862	885	906	928	932
11	IEA	Industry	TWh	ELID	337	342	335	330	345	351	359	364	350
12	IEA	Transport	TWh	ELTR	17	18	18	18	18	19	19	19	19
13	IEA	Residential	TWh	ELRS	184	192	198	204	221	230	233	236	245
14	IEA	Commercial	TWh	ELCM	210	220	226	231	251	257	266	277	289
15	IEA	Agriculture	TWh	ELAG	2	1	2	1	2	2	2	2	2
16	IEA	Others	TWh	ELOT	19	22	21	26	25	26	27	30	29
17	Structure of consumption				100	100	100	100	100	100	100	100	100
18	ARI	Industry	%	STID	43.9	43.0	41.9	40.8	40.0	39.7	39.6	39.3	37.5
19	ARI	Transport	%	STTR	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.0	2.0
20	ARI	Residential	%	STRS	24.0	24.1	24.8	25.2	25.6	26.0	25.7	25.5	26.2
21	ARI	Commercial	%	STCM	27.3	27.7	28.2	28.5	29.1	29.1	29.4	29.8	31.0
22	ARI	Agriculture	%	STAG	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
23	ARI	Others	%	STOT	2.5	2.8	2.6	3.2	2.9	3.0	3.0	3.2	3.1
24													
25	METI	Electricity Demand	TWh	ELEC	834.6	862.7	869.2	877.2	935.0	958.9	979.6	1,002.4	1,007.9
26	METI	Nuclear	TWh	NUCL	202.3	213.5	223.3	249.3	269.1	291.3	302.2	319.2	332.3
27	METI	Natural Gas	TWh	NAGS	167.1	179.5	178.5	178.0	191.7	195.6	207.6	217.1	225.0
28	METI	Coal and Coal products	TWh	COAL	116.7	124.6	131.7	141.3	155.5	168.7	178.1	191.2	192.0
29	METI	Oil and oil products	TWh	DISL	247.9	236.0	241.3	201.4	238.9	206.8	195.8	168.6	149.8

Data / Model / Simulation / Supply / Supply1 / Blance / Supply2 / Sheet6 / Sh

コマンド

"Data" Sheet of SEE

Define the Code Name for all the variables and input data.



Set Up Code Name

	A	B	C	K	L	M	N	O	P	Q	R	S	T
1	Title and Comments			TREND	1	2	3	4	5	6	7	8	9
2	A	B	C	TIME	1990	1991	1992	1993	1994	1995	1996	1997	1998
3	METI	GDP (Constant 2000 Price)	Billion $	GDP	3,206	3,482	3,749	4,316	4,751	5,005	4,413	4,049	3,824
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10	IEA	Total final consumption	TWh	ELTL	769	795	800	810	862	885	906	928	932
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15	IEA	Agriculture	TWh	ELAG	2	1	2	1	2	2	2	2	2
16	IEA	Others	TWh	ELOT	19	22	21	26	25	26	27	30	29
17	Structure of consumption				100	100	100	100	100	100	100	100	100
18	ARI	Industry	%	STID	43.9	43.0	41.9	40.8	40.0	39.7	39.6	39.3	37.5
19	ARI	Transport	%	STTR	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.0	2.0
20	ARI	Residential	%	STRS	24.0	24.1	24.8	25.2	25.6	26.0	25.7	25.5	26.2
21	ARI	Commercial	%	STCM	27.3	27.7	28.2	28.5	29.1	29.1	29.4	29.8	31.0
22	ARI	Agriculture	%	STAG	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
23	ARI	Others	%	STOT	2.5	2.8	2.6	3.2	2.9	3.0	3.0	3.2	3.1
24													
25	METI	Electricity Demand	TWh	ELEC	834.6	862.7	869.2	877.2	935.0	958.9	979.6	1,002.4	1,007.9
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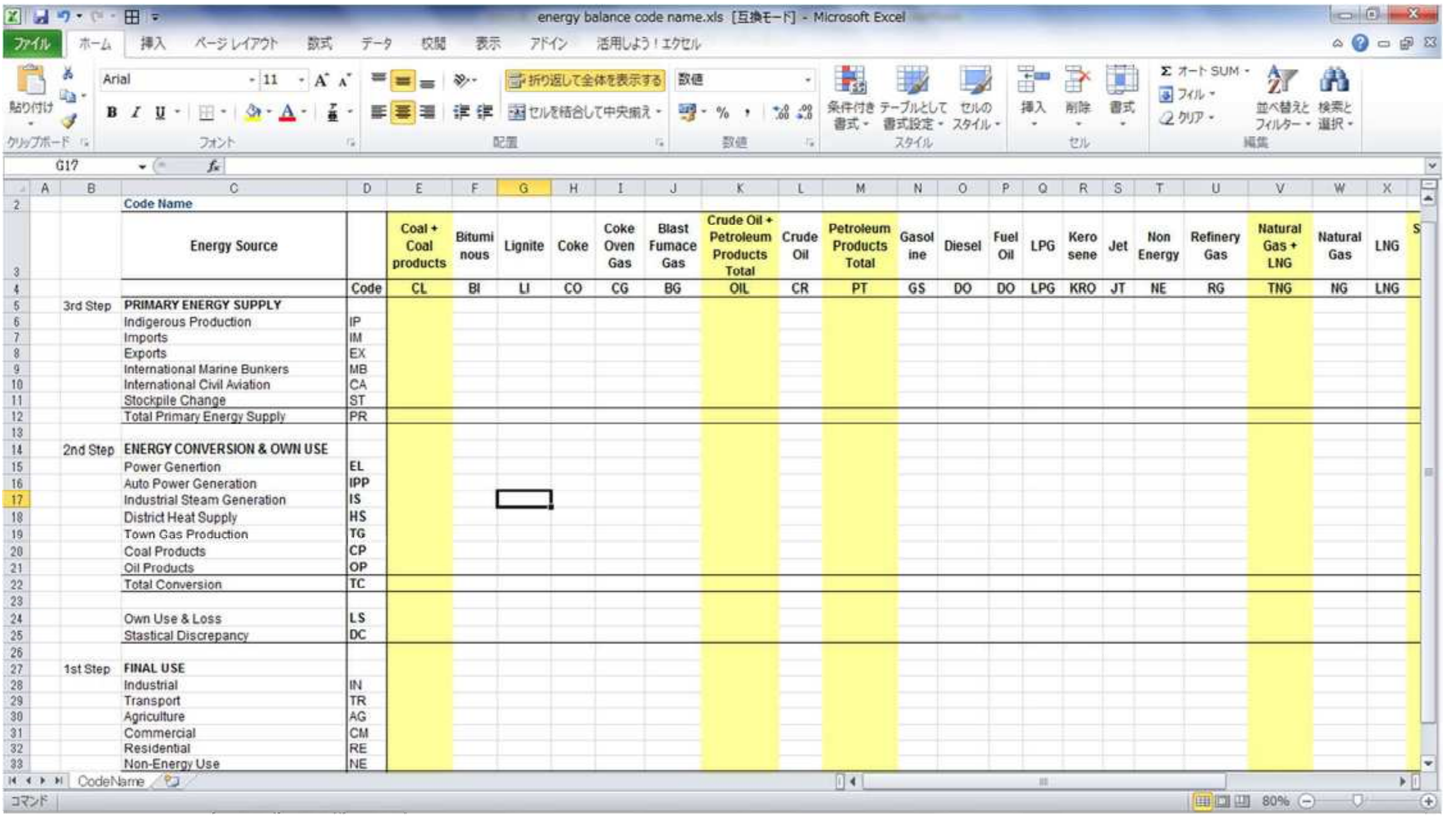
Data / Model / Simulation / Supply / Supply1 / Blance / Supply2 / Sheet6

"Code Name"

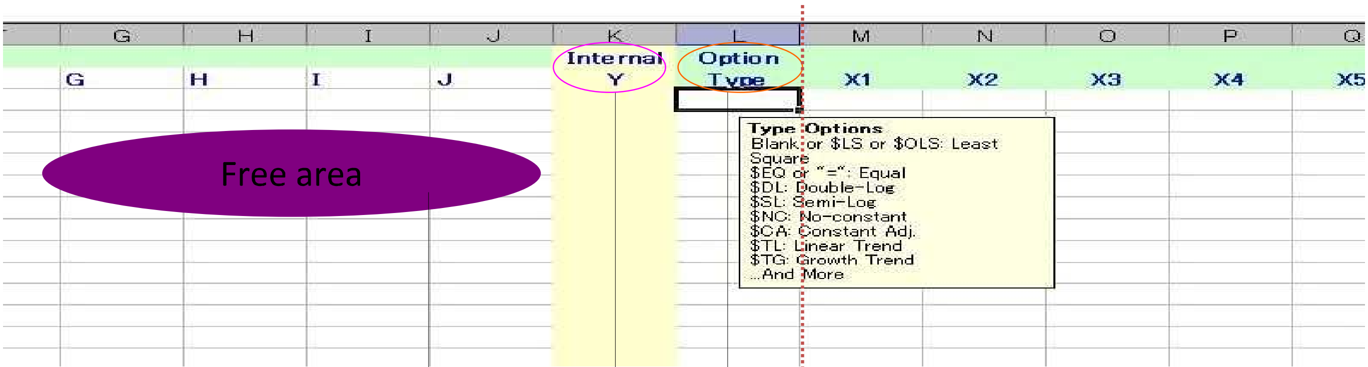


	Energy Source	Code
3rd Step	PRIMARY ENERGY SUPPLY	
	Indigerous Production	IP
	Imports	IM
	Exports	EX
	International Marine Bunkers	MB
	International Civil Aviation	CA
	Stockpile Change	ST
	Total Primary Energy Supply	PR
2nd Step	ENERGY CONVERSION & OWN USE	
	Power Genertion	EL
	Auto Power Generation	IPP
	Industrial Steam Generation	IS
	District Heat Supply	HS
	Town Gas Production	TG
	Coal Products	CP
	Oil Products	OP
	Total Conversion	TC
	Own Use & Loss	LS
	Stastical Discrepancy	DC
1st Step	FINAL USE	
	Industrial	IN
	Transport	TR
	Agriculture	AG
	Commercial	CM
	Residential	RE
	Non-Energy Use	NE

Energy Source	Code
Coal + Coal products	CL
Bituminous	BI
Lignite	LI
Coke	CO
Coke Oven Gas	CG
Blast Fumace Gas	BG
Crude Oil + Petroleum Products Total	OIL
Crude Oil	CR
Petroleum Products Total	PT
Gasoline	GS
Diesel	DO
Fuel Oil	DO
LPG	LPG
Kerosene	KRO
Jet	JT
Non Energy	NE
Refinery Gas	RG
Natural Gas + LNG	TNG
Natural Gas	NG
LNG	LNG

"Model" Sheet of SEE (left half)

Build your model on the left half of the "model" sheet.



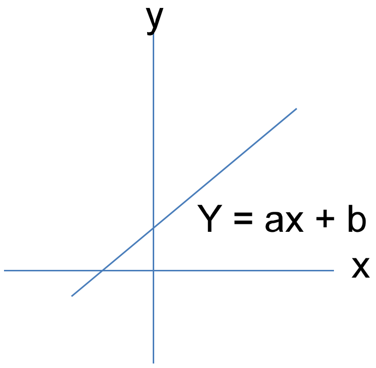
Usually we put the comments of the Code Name here. For example, their meanings, units, and the sources where you get the data, etc…

Input the Code Names of the independent variables here. Pay attention to that the code name should be exactly the same as what you have input in the "data" sheet.

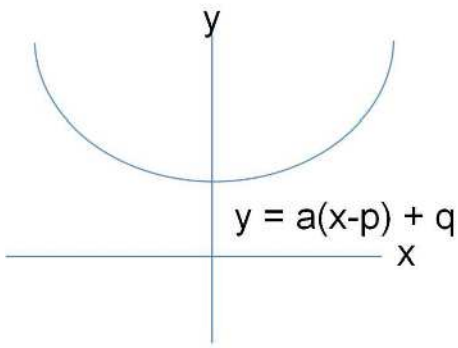
Put the Code Name of the dependent variable y here. Pay attention to that the code name should be exactly the same as what you have input in the "data" sheet

"Option Type" includes ①the form of relationship between Y and X1, X2,… (equal, linear (OLS), Double-log, Semi-log, etc…), and ②how you want Y to change with time (Linear trend, Growth trend, etc…)

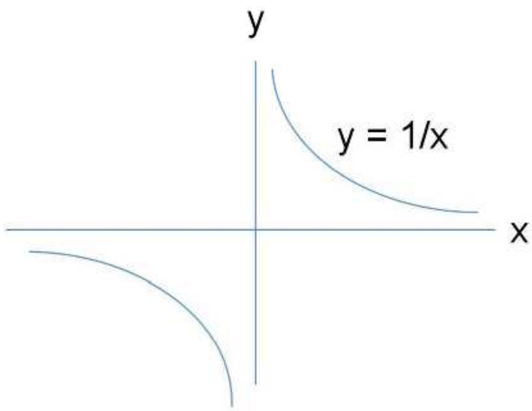
Typical Function Forms



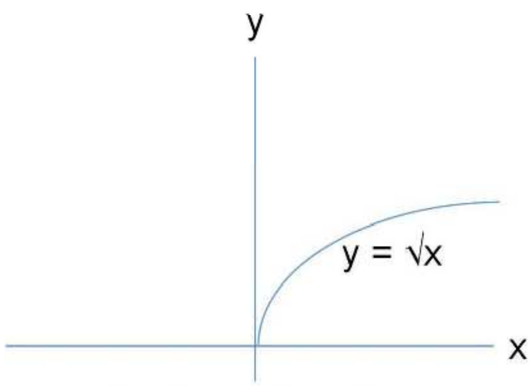
Linear Function



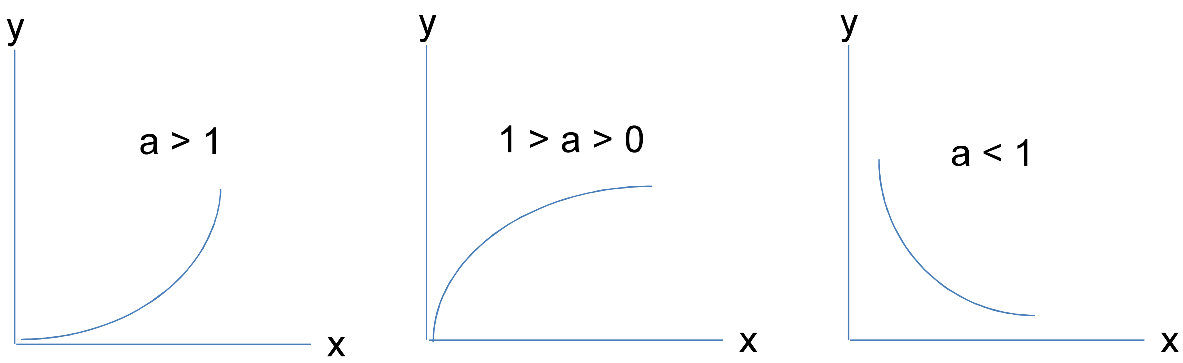
Quadric Function



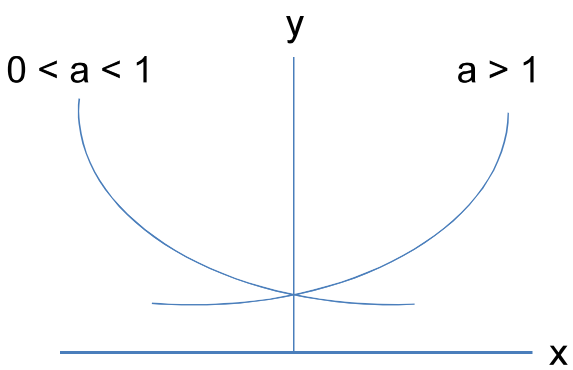
Fractional Function



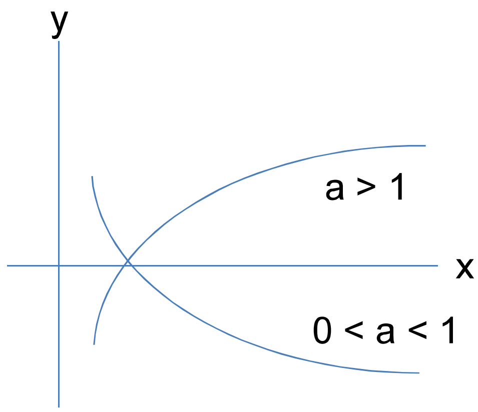
Irrational Function



Power Function ($y = x^a$)



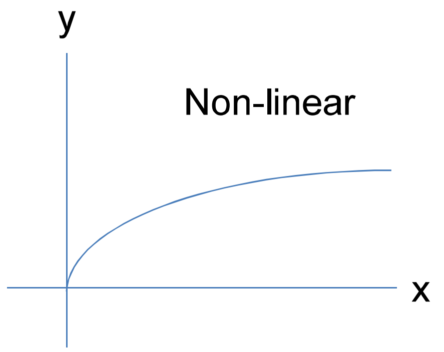
Exponential Function ($y = a^x$)($a > 0$)



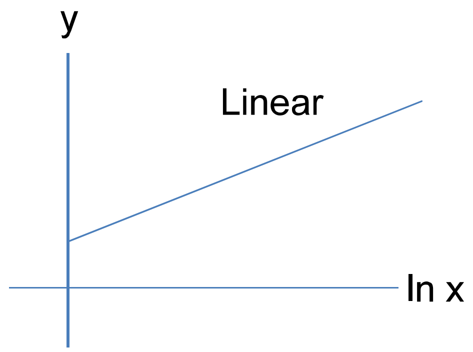
Logarithmic Function ($y = \log_a x$)

Linearization Forms

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 ln X

Typical Function Forms in Simple-e

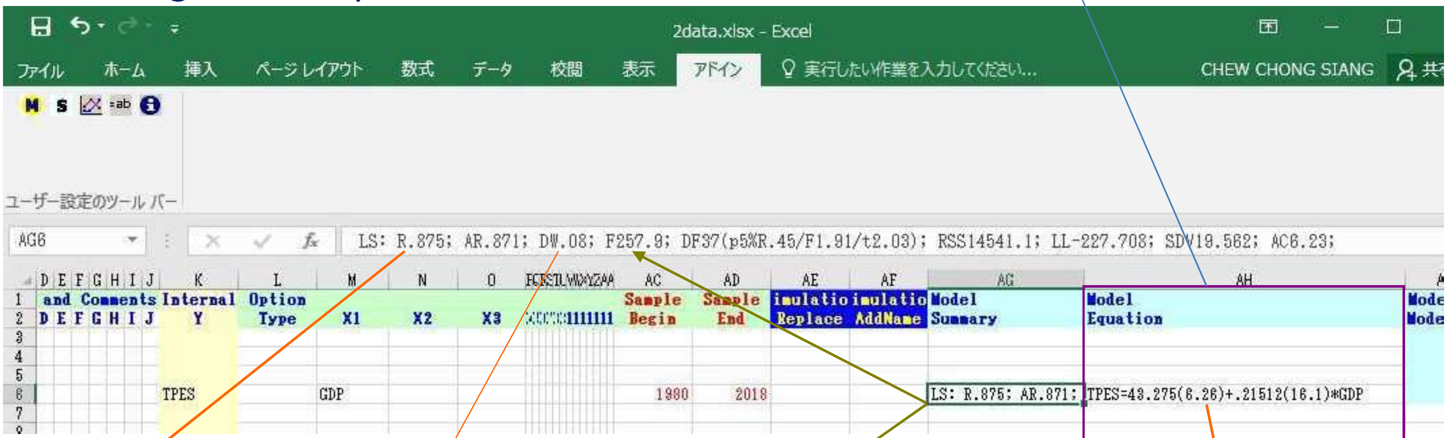
Typical Functional Form	Internal Y	Option Type	X1	X2	X3	X4
Y = a + b*X	DEMAND		GNP.R			
Y = a + b*X + c*Y(−1)	DEMAND		GNP.R	lag1.DEMAND		
LN(Y) = a + b*LN(X)	DEMAND	$DL	GNP.R			
LN(Y) = a + b*X	DEMAND	$SL	GNP.R			
Y = a + b*LN(X)	DEMAND		LN(GNP.R)			
LN(Y) = a + b*LN(X) + c*LN(Y(−1))	DEMAND	$DL	GNP.R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

Inspection the model

Check the fitness of your model on the right half of your model.

Model equation

TPES = 43.275(6.26)+0.21512(16.1)*GDP



① R-squared = 0.875

Parameters for testing the fitness of the model

② T-value = (6.26)

③ Durbin-Watson testing value = 0.08

Notice: After building the model, go to the "main menu" and click the "All through" button. The equation of the model and the parameters for testing the fitness of the model will be displayed on the right half of the "model".

Parameters for testing the fitness of your model (estimation)

(1) R	R-Square, 0 ≤ Explained variance / Total variance ≤ 1, (The larger the better)
(2) AR	Adjusted R-Square, AR ≤ 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) t-value	$\lvert t \rvert \geq 2$: Significant $2 > \lvert t \rvert \geq 1$: Admissible to use $\lvert t \rvert < 1$: Insignificant
(5) DW	Durbin Watson Statistics, 1 < DW < 3 DW = 2 : No serial correlation DW → 0 : Positive correlation DW → 4 : Negative correlation
(6) Dh	Duebinh Statistics with lag, $\lvert Dh \rvert < 2$
(7) Rho	Coefficient of serial correlation, $\lvert Rho \rvert < 1$
(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, $\lvert YX \rvert < 1$
(12) XX	Correlation Coefficient between X's, $\lvert XX \rvert < 0.95$

"Simulation" Sheet of SEE

In "Data" sheet, Input the target year for simulation

Once click the "All through" button in the Main Menu and if there are no bugs in your model, the simulation results (the model outputs) will be displayed in the "simulation" sheet automatically.

References

Macro-economics: Nominal GDP and Real GDP

Nominal gross domestic product is defined as the market value of all final goods and services produced in a geographical region, usually a country. That market value depends on two things: *the actual quantities of goods and services produced* and *their respective prices.*

When it is adjusted for price changes (inflation or deflation), the nominal GDP will be transformed into Real GDP. *Real GDP is a nation's total output of goods and services, adjusted for price changes (that is in constant prices).*

$$NGDP = \sum (p_t \times q_t)$$

$NGDP$	Nominal GDP
p_t	Prices of current year
q_t	Quantities of current year

$$RGDP = \sum (p_b \times q_t)$$

$RGDP$	Real GDP
p_b	Prices of base year
q_t	Quantities of current year

If a set of real GDPs from various years are calculated, each using the quantities from its own year, but *all using the prices from the same base year*, the differences in those real GDPs will reflect only differences in volume.

Mathematic Formula (1)

1. Regression Analysis by use of time-series data

E = f (I, PE)

E: Energy Demand

I: Income (Production), + factor

PE: Energy Price, - factor

2. Energy Intensities

ELi = ai*Yi

FUi = bi*Yi

ai = ELi/Yi. (ai: electricity intensity to activity level (Yi))

bi = FUi /Yi (bi: fuel intensity to activity level (Yi))

3. Share function

FUij (fuel j) = FUi*Sij

Sij: Share of each energy source

Sij = f (Pij / Pi)

P: Energy price

Mathematic Formula (2)

<General energy intensities>

1) Industrial sector

Intensity (i, j) = Energy consumption (i, j)/Production (i, j)

i = type of industry

j = sources of energy (fuels and electricity)

2) Residential & commercial sector

Intensity (j) = Energy consumption (j) / Household

Intensity (j) = Energy consumption (j) / Floor space

j = sources of energy (fuels and electricity)

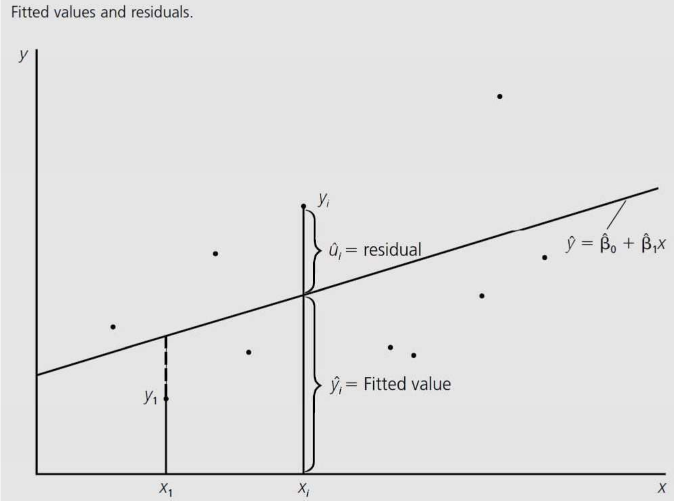
3) Transportation sector

Intensity of passenger transportation = Energy consumption (j) / passenger-km

Intensity of fright transportation = Energy consumption (j) / ton-km

j = sources of energy (fuels and electricity)

R-Squared: Goodness of fit



Fitted values and residuals.

Total sum of squares $SST = \sum_{i=1}^{n} (y_i - \bar{y})^2$

Sample variation in y_i

Explained sum of squares $SSE = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2$

Sample variation in $\hat{y}_i$

Residual sum of squares $SSR = \sum_{i=1}^{n} \hat{u}_i^2$

Sample variation in $\hat{u}_i$

R-squared is defined as:

$$R^2 = SSE / SST = 1 - SSR / SST$$

◆*The ratio of the explained variation compared to the total variation*

◆*R-squared=1 indicates that the data points all lie on the same line (OLS provides a perfect fit to the data). R-squared nearly equals to zero indicates a poor fit of the OLS line.*

Reference: Jeffery M. Woodridge: Introductory Econometrics

t-value: The test of significance

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k + u$$

Once $x_1, x_2, \ldots, x_{j-1}, x_{j+1}, \ldots, x_k$ have been accounted for, whether x_j has a partial effect on the value of *y* (In fact, it is the testing of the null hypothesis: $H_0 : \beta_j = 0$)

$|t| \geq 2$ (t≤-2 or t≥2) : Significant
The factor x_j has significant influence on the value of *y*

$2 > |t| \geq 1$ (-2<t ≤-1 or 1≤ t<2) : Admissible to use
The factor x_j has an influence on the value of *y*

$|t| < 1$ (-1<t<1) : Insignificant
The factor x_j has no influence on the value of *y*

Durbin-Watson test:

What happens if there are auto-correlations among error terms

To test the whether there is autocorrelation or not.

$$DW = \frac{\sum_{t=2}^{n} (\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{n} \hat{u}_t^2}$$

$$y_t = \beta_0 + \beta_1 x_{t1} + \ldots + \beta_k x_{tk} + u_t$$

If DW=2 (1<DW<3), we say there is no autocorrelation;

If DW is near 0 or 4, we say there is autocorrelation.

Sometimes, autocorrelations occur because the model is not "correctly" specified.

For example, some important variables that should be included in the model are not include;

Or the model has the wrong functional form – a linear model is fitted whereas a log-linear model should have been fitted.

Thank you!

Training for Capacity Building on
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Asiam

WG3 Demand Forecast
Material 4

～Electric Power Demand Forecasting Models for Cambodia～part 1

20~24 December 2021
Asiam Research Institute, Inc.
CHEW CHONG SIANG

Contents

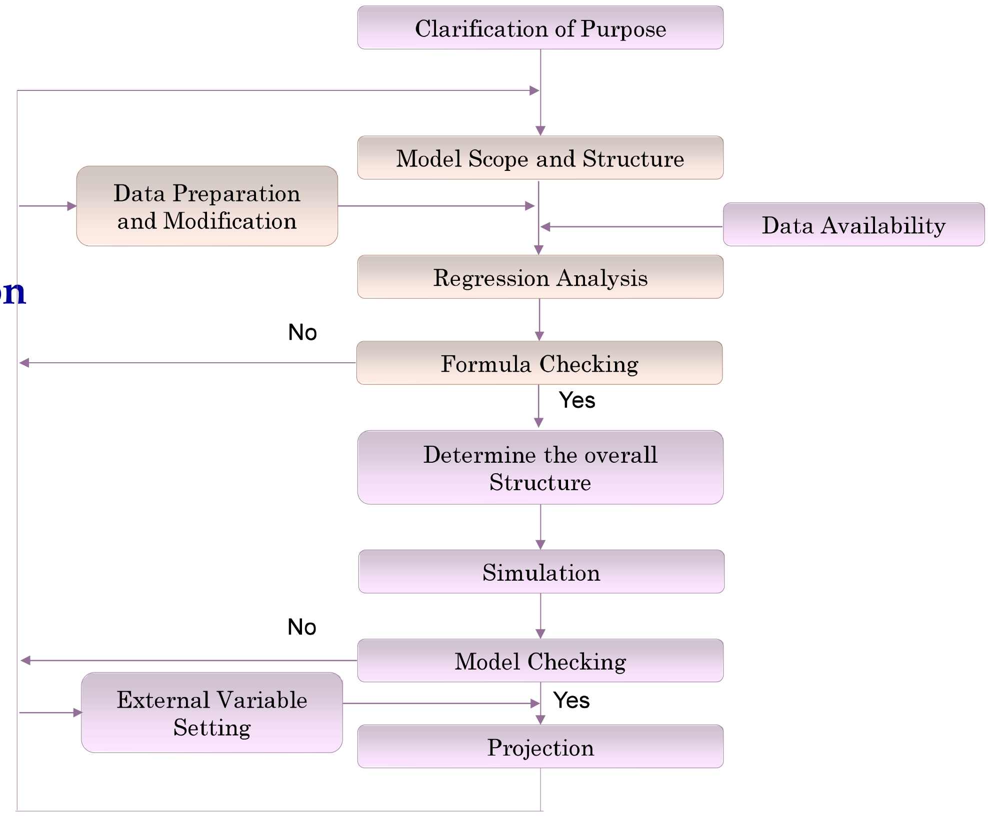
Part 1

1. Method
2. Structure of model
3. Data preparation
4. Macroeconomic sub-model
5. Price Scenario

1. Method

1.1 Procedure

- 80% of the time is spent on data collection.

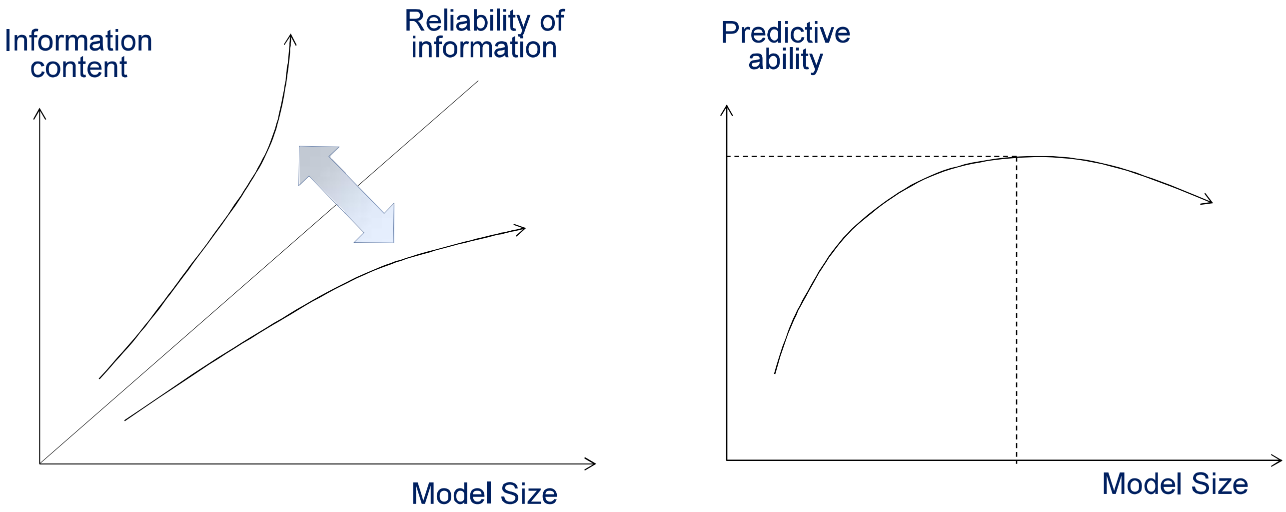


1.2 Model scope Setting

<u>Preparation for model development;</u>

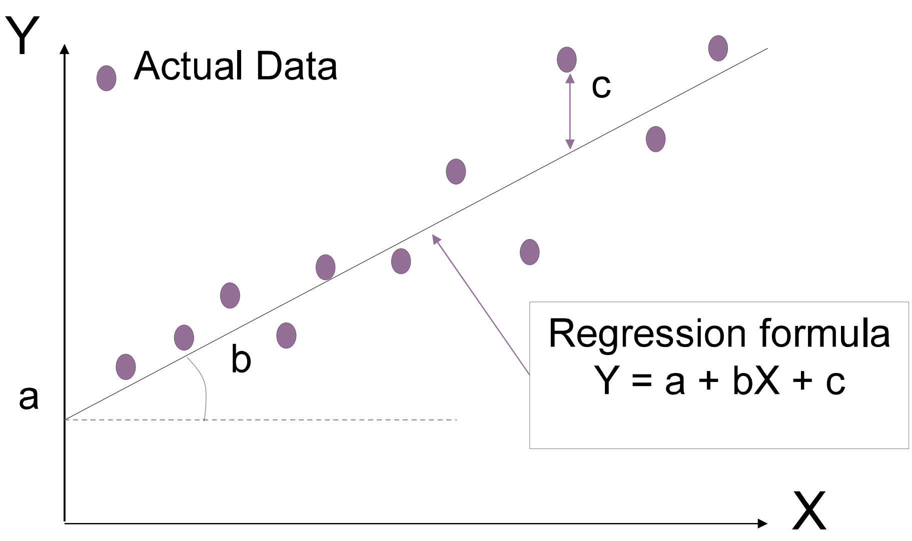
1. Purpose of model building
2. Data availability
3. How far we need the explanation from the model?
4. It is necessary to clarify what should handled in the model and what should given outside the model. (External or internal)
5. Analysis tool (Software)
6. Methodology (Econometric? Simulation?)

1.3 Size of Model



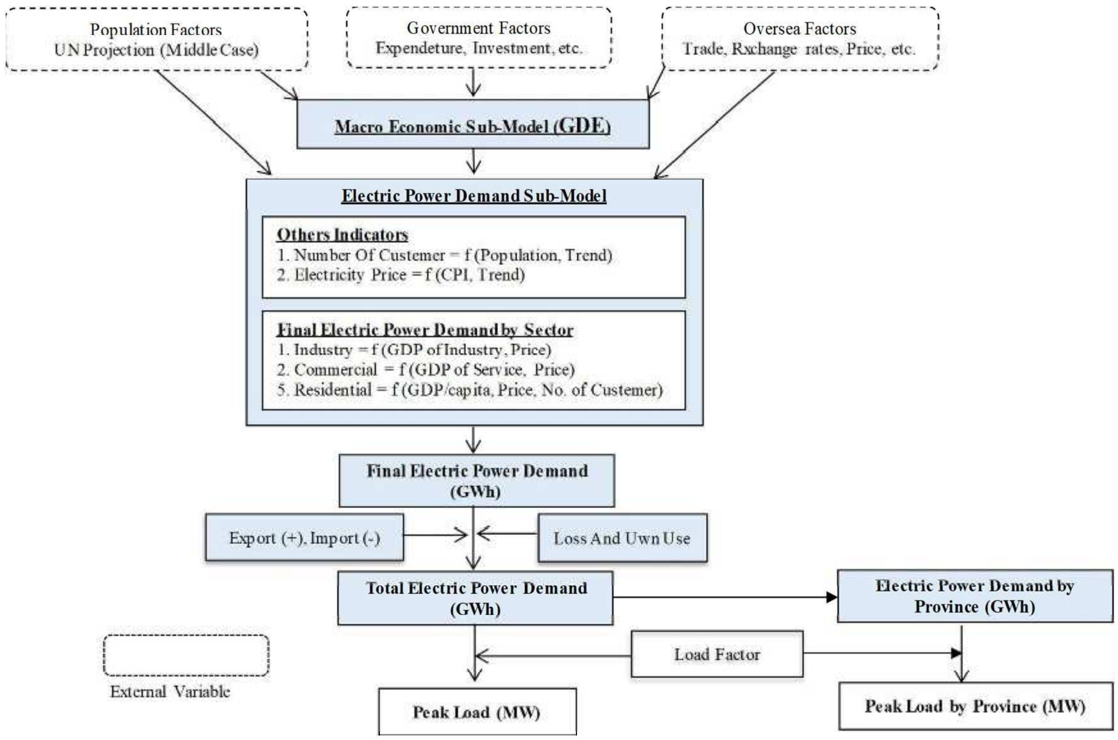
(1) Extending the model will increases the amount of information, but does not increase predictability.
(2) An appropriate model size is desirable. A compact one is good.

1.4 Approach – Econometric model analysis (simulation)



- Ordinary Least Squares (OLS) – Linear least squares method for estimating the unknown parameters (a, b) in a linear regression model by minimizing the sum of the squares of c.

2. Structure of Model



3. Data Preparation

(1) GDP

<u>Available source</u>

- Statistics Department in Cambodia (Central Bank)
- Ministry of Finance
- International Organization: ADB, WB, IMF, UNSTAT

(2) Population

- National Institute of Statistics
- United Nations Population Division

(3) Energy Data

- National Power Company (EDC)
- Electricity Authority Cambodia (EAC)
- Ministry of Mines and Energy (MME)

4. Macro-economic Sub-Model

- **Calculation Process for GDP by sector**
- **Population**

External Variable

Macro economic Block					
Urban population	POPU		lag1.POPU		
Rural population	POPR	=	100-POPU		
GDP at constant 2010 prices in National currency					
Gross Domestic Product (GDP)	GDPR				
Household consumption expenditure	CP	$TG	GDPR/PO	dum.2009	lag1.CP
General government final consumption expenditure	CG	$CA	lag1.CG		
Gross fixed capital formation	IF	$CA	(lag1.CP+I	FDI	
Changes in inventories	J	=	lag1.J		
Exports of goods and services	E	$CA,$DL	lag1.E		
Imports of goods and services	M	$CA	IF	E	EXC
Share of GDP Component					
Agriculture	GDP.AGS	$CA	ln(TREND)		
Industry	GDP.INS	$CA	ln(TREND)		
Services, etc.	GDP.SES	$CA	ln(TREND)		
Others	GDP.OTS	$CA	ln(TREND)		
Total	GDP.TLS	=	100		
Real GDP					
Agriculture	AGR	=	GDPR*(GDP.AGS/GDP.TLS)		
Industry	INR	=	GDPR*(GDP.INS/GDP.TLS)		
Services, etc.	SER	=	GDPR*(GDP.SES/GDP.TLS)		
Others	OTR	=	GDPR*(GDP.OTS/GDP.TLS)		

5. Price Scenario

1) We used inflation and the consumer price index (CPI) as a price variable because the time when we creating this model, we are failed to collect the time series of electricity prices.

2) We assume the inflation rate will increase annually 3% until 2030.

Price Scenario					
Inflation	INFL	=	3		
Inflation, consumer prices (annual growth)	CPI	=	lag1.CPI*(1+INFL/100)		
Inflation, GDP deflator (annual growth)					
Electricity Prices					
Industry					
Residential					
Commercial					
Others					

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WG3 Demand Forecast
Material 5

~Electric Power Demand Forecasting Models for Cambodia~part 2

20~24 December 2021
Asiam Research Institute, Inc.
CHEW CHONG SIANG

Contents

Part 2

1. Electric power demand sub-model
2. Examining model formulas
3. Simulation and confirmation of final results

6. Electric Power Demand Block

Below shows the system equation in each demand sector. Basically, system equations by sectors were created as the following functional relations.

1. Industrial (Manufacturing) Sector
   Electricity demand = f(GDP of Industry , Price for industry)
2. Commercial, Public service and other Sector
   Electricity demand = f(GDP of Commercial, Price for commercial)
3. Residential Sector
   Number of customer = f(electrification ratio)
   Electricity demand = f(electricity consumption/customer, price of households, number of customer)

- Losses: Transmission and distribution losses
- Own use in electricity, CHP and Heat plants

Electric power Block							
Final comsumption by sector		FCEL	=	INEL+REEL+CMEL			
	Industry total (manufacturing, construction and non-f	INEL	$CA,$DL	INR	lag1.INEL		
	Residential	REEL	$CA,$DL	POP	Lag1.REE	CPI	
	Commercial, public services and others	CMEL	$DL	SER	CPI	lag1.CMEL	
Own use in electricity, CHP and heat plants		OWN	=	FCEL*0.025			
Losses		LOSS	=	lag1.LOSS*(1+14/100)			
Export		EXEL	=	0			
Total Electricity Demand		TLEL	=	INEL+REEL+CMEL+OWN+LOSS+EXEL			
		NOCUS		lag1.NOCUS			

6. Examining model

Formula Checking, Simulation, Verification and confirmation of final results.

(1) Industrial Sector

- Regression formula:

  LN (INEL) = 1.49(2)+0.24(2.34) * LN(INR)
  + 0.73(6.99) * LN(LAG1.INEL) + 0.07(2.79)*DUM.2010

  Where, R square = 0.956
  Durbin Watson Ration = 1.82

  INR = Industry GDP
  INEL = Electricity demand in industry sector
  Dum.2010 = Dummy year 2010
  LAG1.INEL = Previous year INEL

- $DL = Double logarithmic function

(3) Domestic Sector

Regression formula:

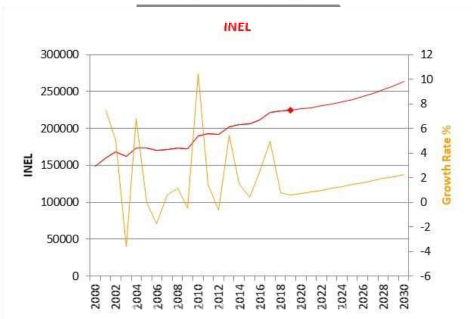
REEL=-6525(-0.38) + 14399(3.36) * GDPR/POP - 12603500(-2.32) * REELP/CPI + 0.83(11.9) * LAG1.REEL - 13332(-2.07) * DUM.2016

Where, R square = 0.977
Durbin Watson Ration = 1.89

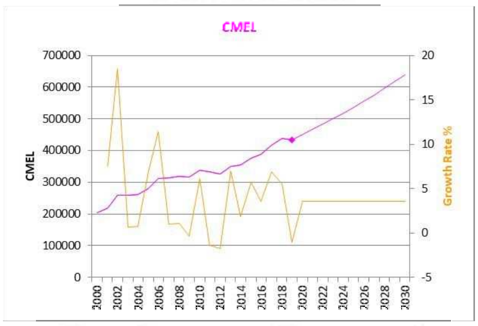
POP = Population
REEL = Electricity demand in domestic sector
LAG1.REEL = Previous year REEL
REELP = Domestic Tariff
CPI = Consumer Price Index

7. Simulation

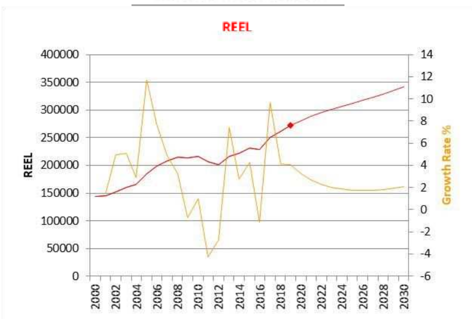
Industry



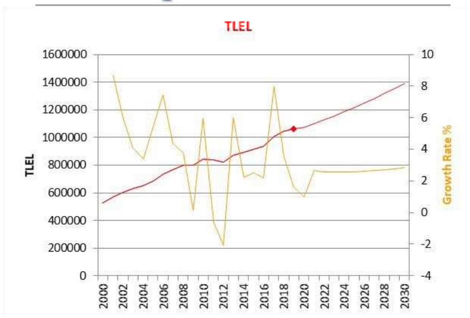
Commercial



Domestic



Total power Demand



8. Electric Power Demand by Provinces

(1) GDP

Available source

- Statistics Department in Cambodia (Central Bank)
- Ministry of Finance
- International Organization: ADB, WB, IMF, UNSTAT

(2) Population

- National Institute of Statistics
- United Nations Population Division

(3) Energy Data

- National Power Company (EDC)
- Electricity Authority Cambodia (EAC)
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4. Macro-economic Sub-Model

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External Variable

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5. Price Scenario

1) We used inflation and the consumer price index (CPI) as a price variable because the time when we creating this model, we are failed to collect the time series of electricity prices.

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Price Scenario						
Inflation		INFL	=	3		
Inflation, consumer prices (annual growth)		CPI	=	lag1.CPI*(1+INFL/100)		
Inflation, GDP deflator (annual growth)						
Electricity Prices						
Industry						
Residential						
Commercial						
Others						

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Asiam

WG3 Demand Forecast

～Method and structure of model～
OJT-Material 1

16 February 2022

Asiam Research Institute, Inc.
CHEW CHONG SIANG

OJT-Contents

Material 1 - Method and structure of model

Material 2 - Electricity demand analysis

Material 3 - Model evaluation

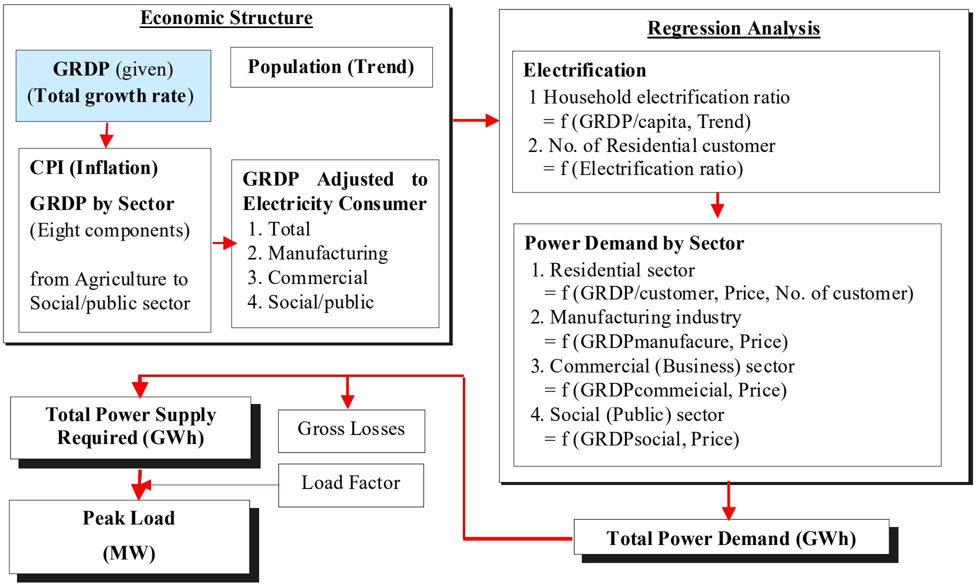
Material 4 - Projection

Material 1
Method and structure of model

1.The Type of Energy Model

Types	Purpose of Use			
	Evaluation of Measures		Scenario	
	Technology	System and Economy		
a. Optimization	MARKAL Heafele/IES	ETA-MACRO Global 2100	CETA	Our Challenge
b. Econometric		Jorgenson-Wilcoxen OECD/GREEN	NEMS (US/DOE) FUGI	
c. Simulation				
(1) Bottom-Up			MEDEE (IEEJ) ECMP (IEEJ)	
(2) Market Equilibrium		Edmonds-Reflly IEA Model		
(3) System Dynamic			Roman Club/World III	

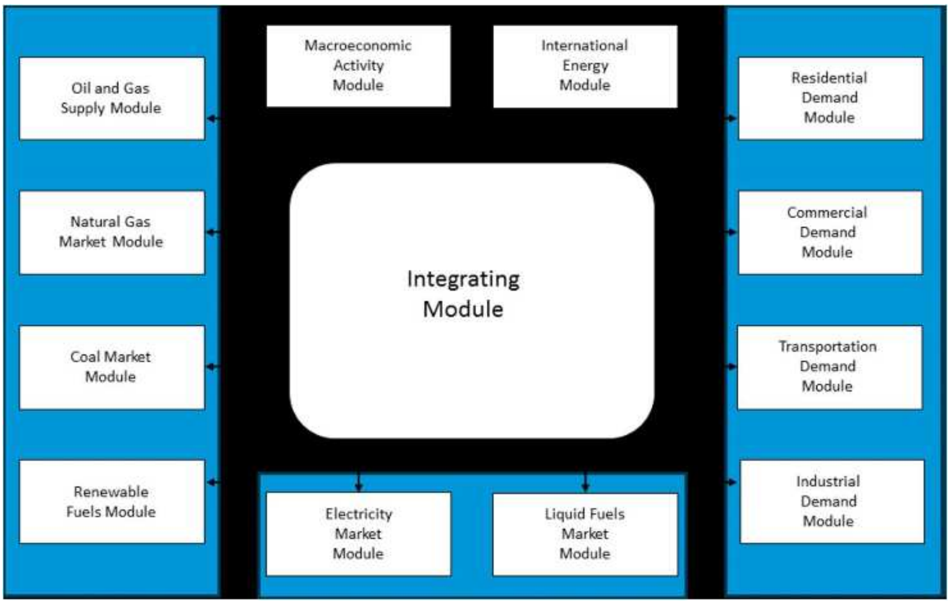
1.1 Example-1; Regional Power Demand Model (Japan)



1.2 Example-2.1; US EIA US National Energy Modeling System (NEMS)

NEMS

1. Represents the behavior of energy markets and their interactions with the U.S. economy.
2. Reflects market economics, industry structure, and existing energy policies and regulations that influence market behavior.
3. Consists of 13 modules: integrating module provides the mechanism to achieve a general market equilibrium among all the other modules.

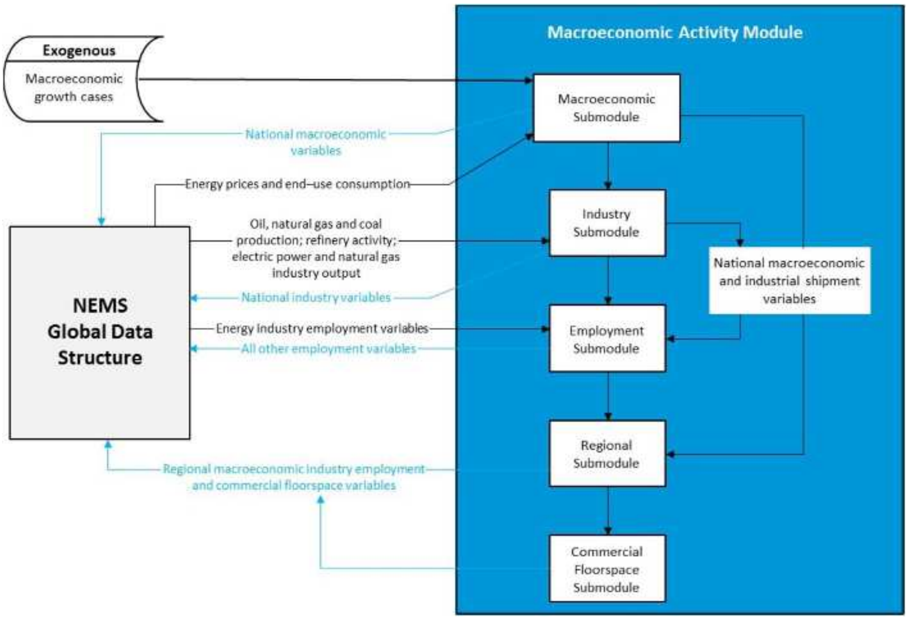


Source; US EIA NEMS Overview 2018, https://www.eia.gov/outlooks/aeo/nems/documentation/

1.2 Example-2-2; US EIA
NEMS-Macroeconomic Activity Module

MAM Structure

1. MAM links NEMS to the rest of the economy by providing projections of economic driver variables for use by the supply, demand, and conversion modules of NEMS.
2. NEMS employs the IHS Markit Ltd. model of the U.S. economy in the EViews environment.
3. All of the MAM models are linked to provide a fully integrated approach to estimating economic activity at the national, industrial and regional levels.

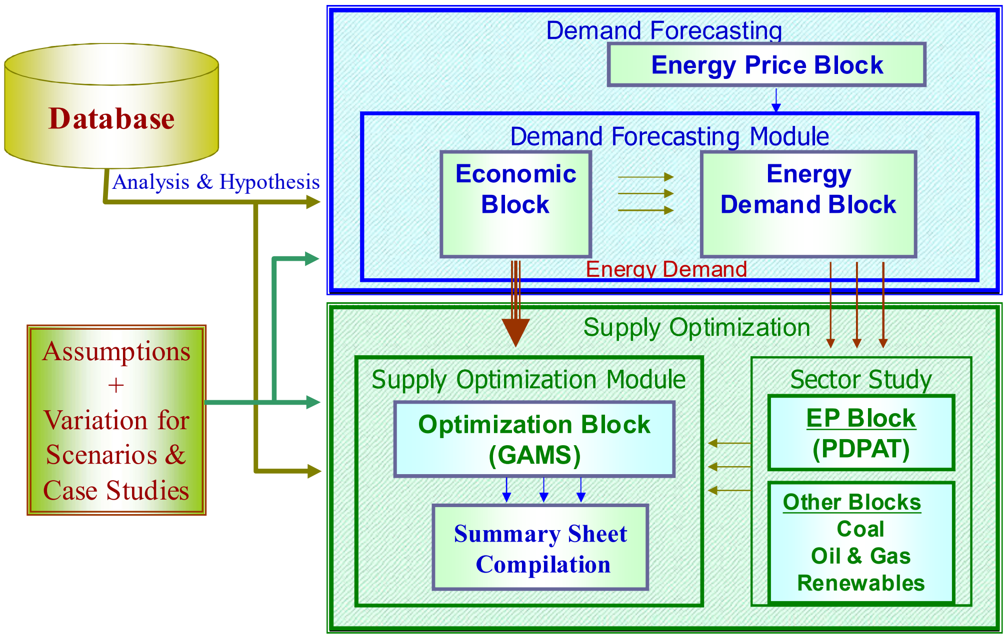


Source; US EIA NEMS Overview 2018, https://www.eia.gov/outlooks/aeo/nems/documentation/

1.3 Example-3; IEEJ Model
for the Philippine Energy Plan (PEP)

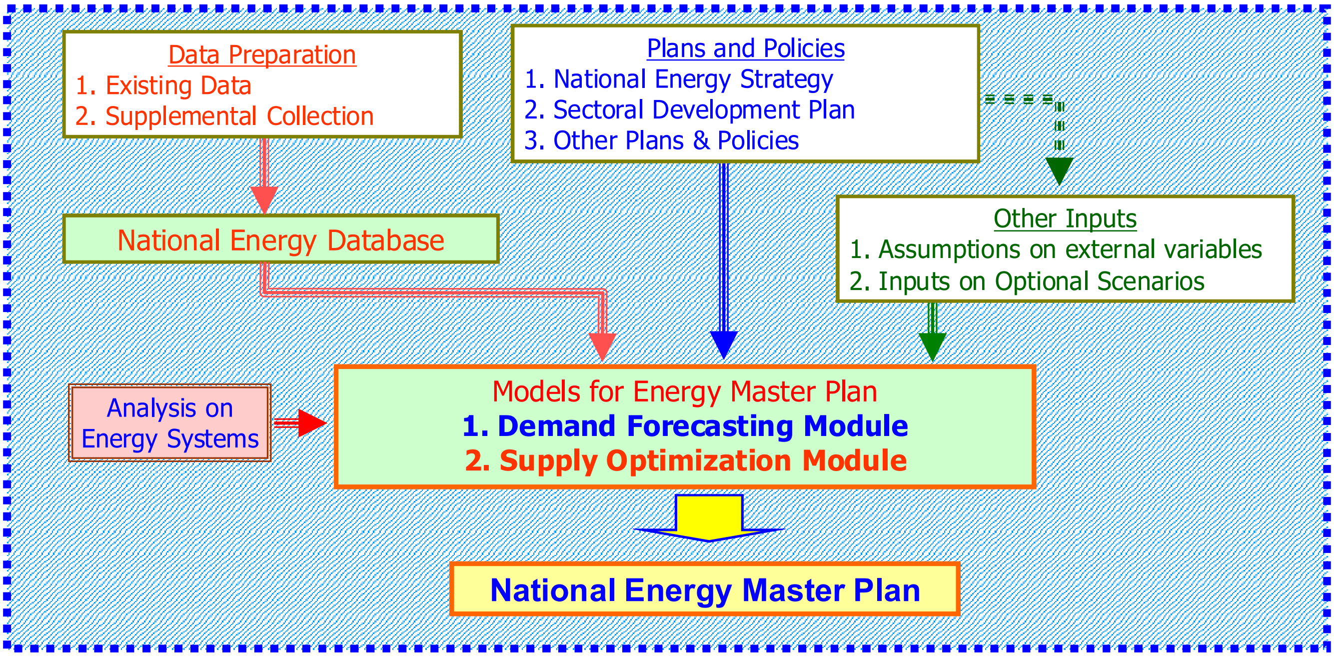
IEEJ Model for PEP

1. Model comprises demand module developed on Simple-E and supply module applying GAMS.
2. Energy demand is forecast first by the demand module.
3. Against the projected demand outlook, energy supply is optimized by the supply module.

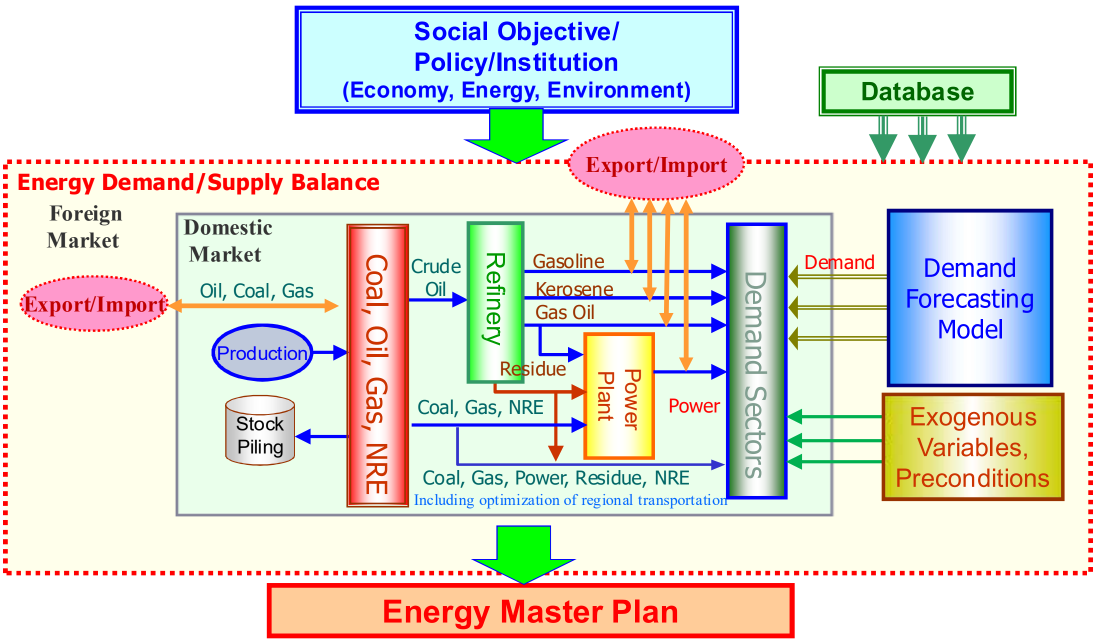


Source; IEEJ/TEPCO "JICA Study on Philippine Energy Plan Formulation", 2008

1.4 Example-4; IEEJ Model
Data Flow



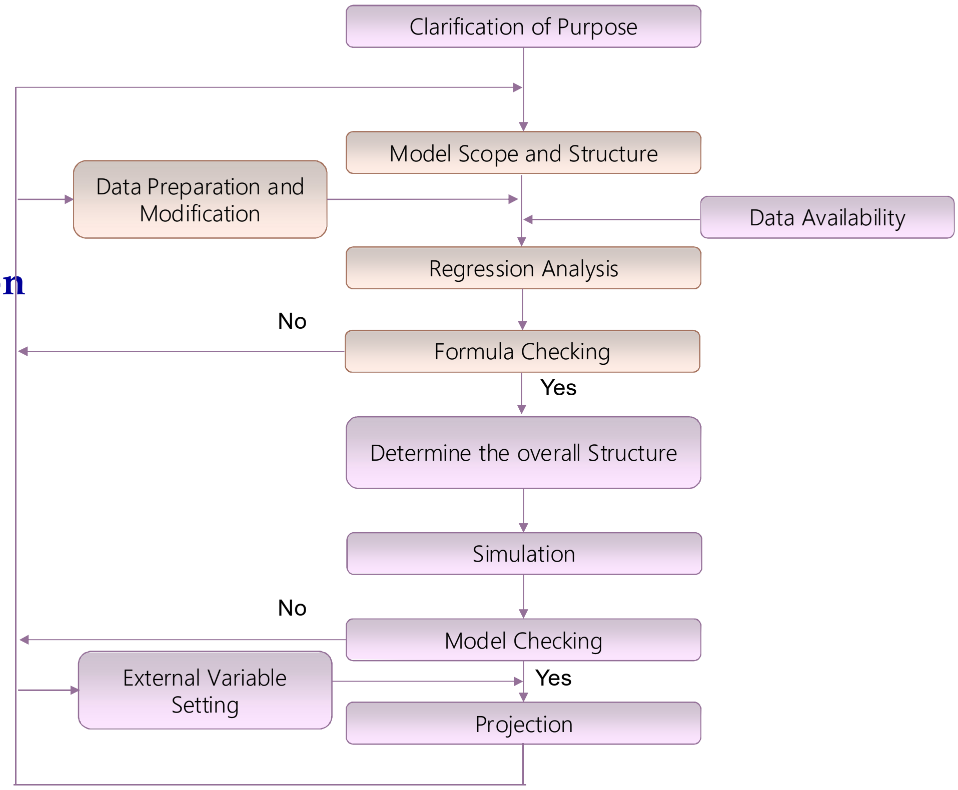
1.4 Example-4; IEEJ Model
Structure of Supply Optimization Module



2. Method

2.1 Procedure

- 80% of the time is spent on data collection.

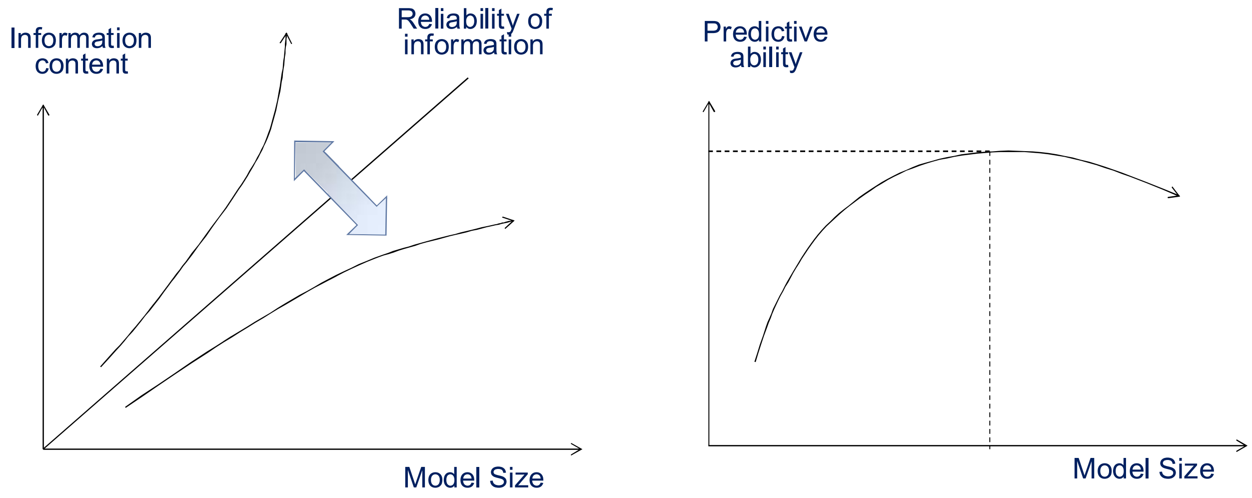


2.2 Model scope Setting

<u>Preparation for model development;</u>

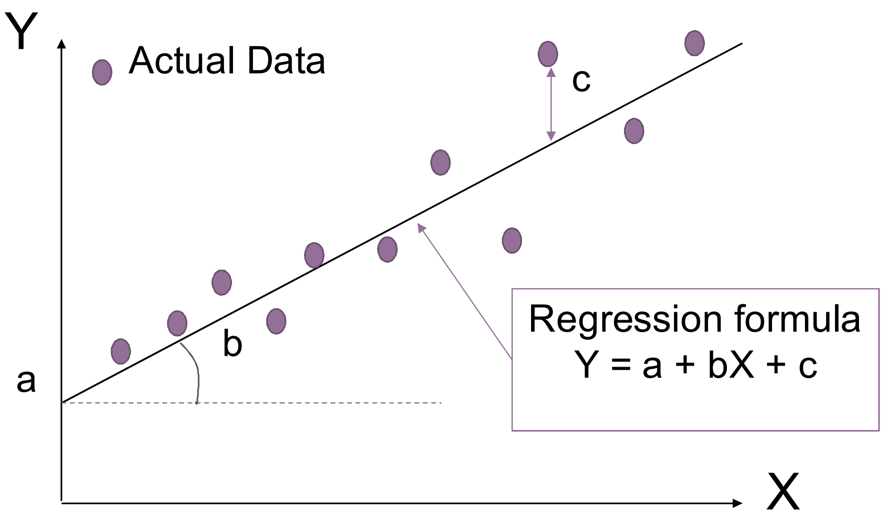
1. Purpose of model building
2. Data availability
3. How far we need the explanation from the model?
4. It is necessary to clarify what should handled in the model and what should given outside the model. (External or internal)
5. Analysis tool (Software)
6. Methodology (Econometric? Simulation?)

2.3 Size of Model



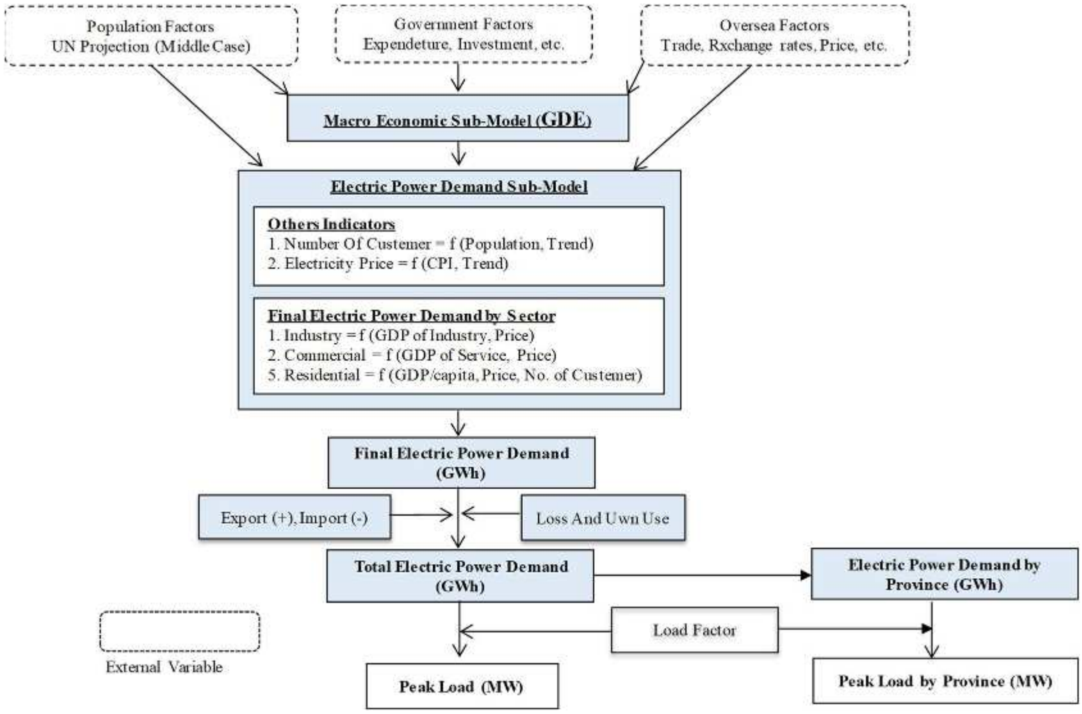
(1)Extending the model will increases the amount of information, but does not increase predictability.
(2)An appropriate model size is desirable. A compact one is good.

2.4 Approach – Econometric model analysis (simulation)



- **Ordinary Least Squares (OLS) – Linear least squares method for estimating the unknown parameters (a, b) in a linear regression model by minimizing the sum of the squares of c.**

3. Structure of Model



4. Data Preparations

(1) GDP

Available source

- Statistics Department in Cambodia (Central Bank)
- Ministry of Finance
- International Organization: ADB, WB, IMF, UNSTAT

(2) Population

- National Institute of Statistics
- United Nations Population Division

(3) Energy Data

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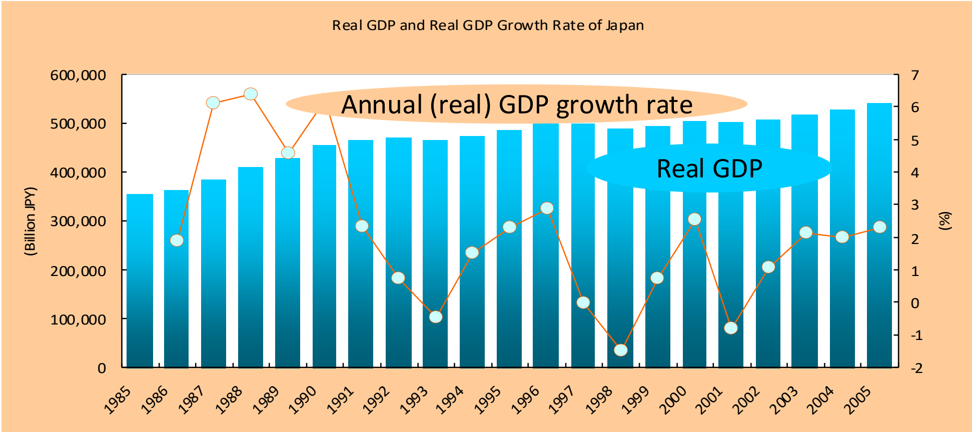
- Ministry of Mines and Energy (MME)

5. Exercises
Macro-economics: Real GDP Growth Rate



- Definition of GDP growth rate $RGDPgrowthrate_t = \frac{(RGDP_{t+1} - RGDP_t)}{RGDP_t} \times 100\%$
- How to calculate the RGDP of the next year given the RGDP of this year and the expected GDP (real) growth rate: $RGDP_{t+1} = RGDP_t \times (1 + RGDPgrowthrate_t)$

Macro-economics: Nominal GDP and Real GDP

Nominal gross domestic product is defined as the market value of all final goods and services produced in a geographical region, usually a country. That market value depends on two things: *the actual quantities of goods and services produced and their respective prices.*

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$NGDP = \sum (p_t \times q_t)$

$NGDP$	Nominal GDP
p_t	Prices of current year
q_t	Quantities of current year

$RGDP = \sum (p_b \times q_t)$

$RGDP$	Real GDP
p_b	Prices of base year
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If a set of real GDPs from various years are calculated, each using the quantities from its own year, but *all using the prices from the same base year*, the differences in those real GDPs will reflect only differences in volume.

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Asiam

WG3 Demand Forecast

~Electricity demand analysis~
OJT-Material 2

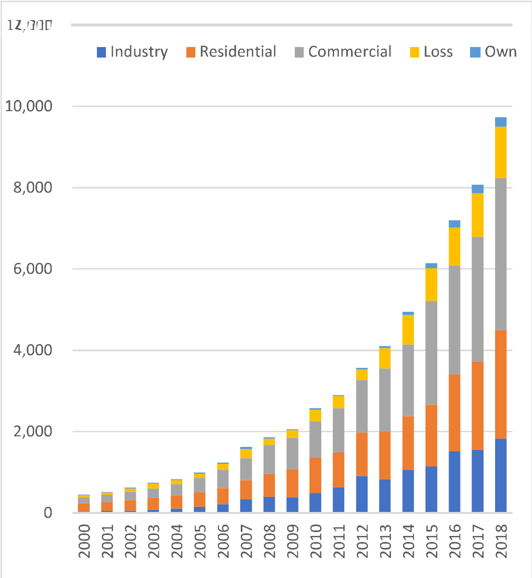
28 February 2022
Asiam Research Institute, Inc.
CHEW CHONG SIANG

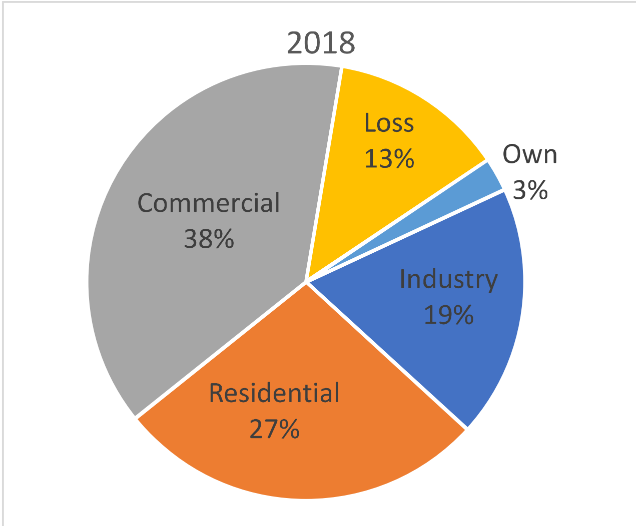
Material 2
Electricity demand analysis

1. Structure of electricity demand
2. Current condition
3. Provinces

1. Structure of electricity demand

1.1 Electricity demand by sector





1.2 Electricity demand by sector – Growth Rate

	Industry	Residential	Commercial	Loss	Own	Total
2001	21.6	10.0	18.1	12.0	13.3	13.9
2002	35.0	16.1	17.8	51.8	14.7	22.2
2003	25.9	13.9	15.1	34.1	12.8	18.2
2004	38.5	11.3	17.7	-8.8	9.1	13.0
2005	35.7	12.5	28.6	2.9	16.7	19.6
2006	50.2	6.3	29.7	32.7	25.0	24.2
2007	56.8	17.9	22.1	52.1	57.1	31.3
2008	15.1	25.6	26.6	-24.1	-45.5	14.7
2009	-0.3	18.5	11.9	8.5	-13.3	10.7
2010	26.1	27.4	14.3	60.7	11.5	24.9
2011	28.6	-1.7	21.6	3.5	6.9	12.9
2012	42.9	26.4	18.1	-11.5	35.5	23.1
2013	-8.9	9.9	20.2	90.5	23.8	15.0
2014	28.6	11.5	14.3	43.7	73.1	20.7
2015	7.8	15.4	43.8	13.0	43.3	24.1
2016	33.1	24.3	4.9	15.6	44.2	17.2
2017	2.3	14.7	14.9	14.7	12.8	12.1
2018	18.0	22.7	22.0	17.5	15.3	20.7
Average	25.8	16.4	21.1	20.9	17.8	19.9

Electricity demand (2000-2018)

Average Growth: 19.9%

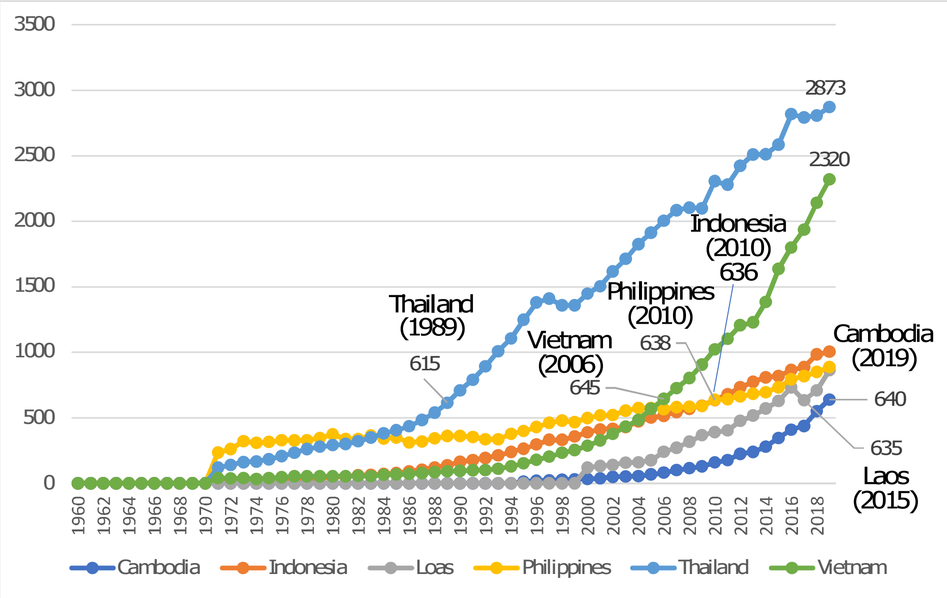
- Growth very fast
- All Sector

Points;

- When the peak coming?
- Analyses each of the sector find the key driver
- How to take care the Loss

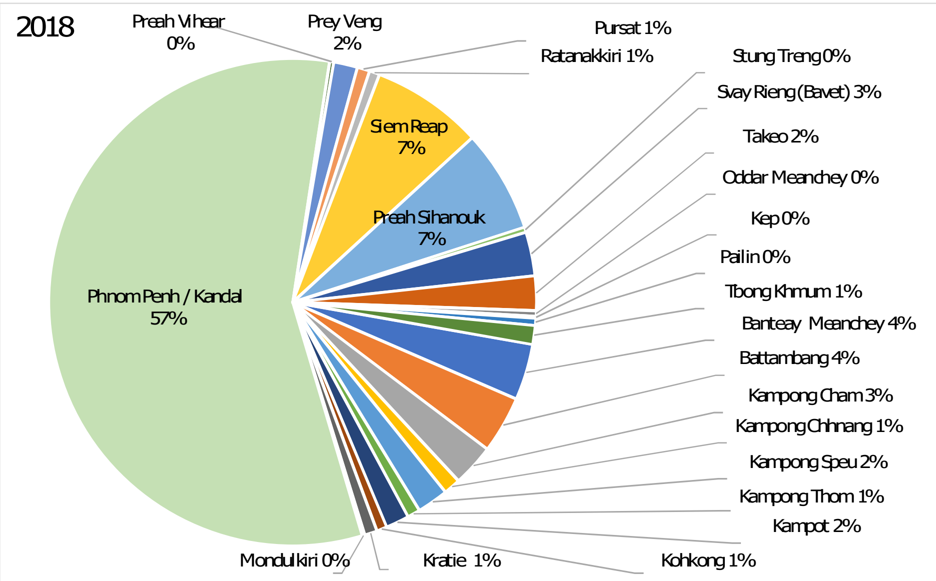
2. Current Condition

2.1 Electricity consumption/population (kWh per capita)



- Compare to neighboring country
  - kWh per capita
  - GDP per capita
  - Electricity demand growth
- Exploring future development potential
- Conform the growth Pattern for Cambodia

3. Provinces



Phnom Penh: 57%
Siem Reap: 7%
Preah Sihanouk: 7%
Total three: 71%

Next Step:
Focus on above three provinces to construct a demand modeling for provinces.

Training for Capacity Building on
IPP Project Evaluation (JICA)

Asiam

WG3 Demand Forecast - OJT

Material 3 - Model evaluation
Material 4 - Projection

28 February 2022
Asiam Research Institute, Inc.
CHEW CHONG SIANG

Contents

Material 3 – Model Evaluation

3.1 Function Forms

Typical functional forms written in the model sheet

G	H	I	J	Internal Y	Option Type	X1	X2	X3	X4	X5
Typical Functional Form										
Y = a + b*X				FNEL		GDP				
Y = a + b*X + c*Y(-1)				FNEL		GDP	lag1.FNEL			
LN(Y) = a + b*LN(X)				FNEL	$DL	GDP				
LN(Y) = a + b*X				FNEL	$SL	GDP				
Y = a + b*LN(X)				FNEL		LN(GDP)				
LN(Y) = a + b*LN(X) + c*LN(Y(-1))				FNEL	$DL	GDP	lag1.FNEL			
LN(Y) = a + b*LN(X1) + c*LN(Y(-1)) + d*X2				FNEL	$DL	GDP	lag1.FNEL	exp(TREND)		
				Ln(FNEL)		LN(GDP)	LN(PRICE)			
				FNEL	=	EXP(Ln_FNEL)				
Y = a + b*X1 + c*X2				FNEL		GDP	PRICE			
Y = a + b*X1 + c*X2 + d*Y(-1)				FNEL		GDP	PRICE	lag1.FNEL		
LN(Y) = a + b*LN(X1) + c*LN(X2)				FNEL	$DL	GDP	PRICE			
LN(Y) = a + b*X1 + c*X2				FNEL	$SL	GDP	PRICE			
Y = a + b*LN(X1) + c*LN(X2)				FNEL		LN(GDP)	LN(PRICE)			
Y = a + b*LN(X1) + c*X2				FNEL		LN(GDP)	PRICE			
LN(Y) = a + b*LN(X1) + c*LN(X2) + d*LN(Y(-1))				FNEL	$DL	GDP	PRICE	lag1.FNEL		
LN(Y) = a + b*LN(X1) + c*LN(X2) + d*LN(Y(-1)) + e*X3				FNEL	$DL	GDP	PRICE	lag1.FNEL	exp(TREND)	

3.2 Fitness of Equation by Regression Analysis

1) R	R-Square, $0 \le$ Explained variance / Total variance ≤ 1, (The larger the better)	
2) AR	Adjusted R-Square, AR ≤ 1, (The larger the better)	
3) SD	Standard Deviation: SD = $(\sum e^2 /(n-k))^{1/2}$, e = Residual, n = Sample size, k = Number of independent variables	
4) DW	Durbin Watson Statistics, $1 < DW < 3$ DW = 2	: No serial correlation
	DW $\rightarrow$ 0	: Positive correlation
	DW $\rightarrow$ 4	: Negative correlation
5) Dh	Durbin h Statistics with lag, $\lvert Dh \rvert < 2$	
6) t-value	$\lvert t \rvert \ge 2$	: Significant
	$2 > \lvert t \rvert \ge 1$	: Admissible to use
	$\lvert t \rvert < 1$	: Insignificant
7) Rho	Coefficient of serial correlation, $\lvert Rho \rvert < 1$	
8) DF	Degree of Freedom, DF > 1 (The lager the better)	
9) F	F-value, F-Statistic: 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 Xs, $\lvert YX \rvert < 1$	
12) XX	Correlation Coefficient between Xs, $\lvert XX \rvert < 0.95$	

3.3 Modeling by Sector
(1) Industrial

Electricity demand of industry sector (INEL)
=Industry GDP (GDPIN) + (Electricity tariff (INELP)/Index Price(CPI))

Example;

Ln (INEL)= -16.67 (-4.48) +1.49 (7.22)*Ln (GDPIN) -0.76 (-2.75)*Ln (INELP/CPI)
Where, R square = 0.93
Durbin Watson ratio = 1.17

(2) Residential

Calculation for Number of customer
CUST (Number of customer)
= (Population/Number of Family)* Electrification ratio

Electricity demand of Residential (REEL)
= GDP/Number of customer (CUST) + (Electricity tariff (REELP)/Index Price(CPI) + Number of customer(CUST)
Example;
Ln (REEL)= -6.36 (-6.92) +0.47 (6.79)*Ln (GDP/CUST) -0.28 (-7.23)*Ln (REELP/CPI) +0.49 (6.95)*Ln (CUST) +0.69 (12.8)*Ln (lag1.REEL)
Where, R square = 0.99
Durbin Watson ratio = 2.39

(3) Commercial

Electricity demand of Commercial (CMEL)
=Commercial GDP (GDPCM) + (Electricity tariff (CMELP)/Index price (CPI))

Ln (CMEL)= -25.72 (-8.08) +1.91 (11.2)*Ln (GDPCM) -0.699 (-5.35)*Ln (CMELP/CPI)

Where, R square = 0.98
Durbin Watson ratio = 1.36

(4) Public

Electricity demand of Public (PUEL)
=Public GDP (GDPPU) + (Electricity tariff (PUELP)/Index Price (CPI))

Example;
Ln (PUEL)= -2.78 (-2.81) +0.28 (3.67)*Ln (GDPPU) -0.80 (-3.24)*Ln (PUELP/CPI)
Where, R square = 0.99
Durbin Watson ratio = 2.24

Material 4 – Projection

4.1 Scenario Setting for Model Analysis

1. Scenarios may be set corresponding to the future socio-economic outlook, social targets and policy options, which are considered difficult or inappropriate for forecasting by the model.
2. In general energy/environment analysis, scenarios are set on future development of socio-economic elements; such as population growth rate, economic growth rate, crude oil prices, currency exchange rate, monetary/fiscal policies, industrial structure change, energy structure target (energy conversion, energy import/export), energy tariff options, energy efficiency target, GHG emissions target, new/renewable energy introduction policy, environmental policies, etc.
3. A scenario for model analysis comprises a set of assumptions and projections numerically expressed on these elements.

(1) Scenario Setting by Data Sheet; Projection of Variables

1. Scenarios should be prepared in numerical values and given to the model as a set of projected external variables in the "Data" sheet.
2. For case studies, different scenarios may be examined changing the projection for variables and running the model for each such set.

14	15	16	17	18	19	20	21	22	23	24	25	26
1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
167	180	188	196	208	218.4	229.32	240.786	252.8253	265.4666	278.7399	292.6769	307.3107
239.7	258	281.7	288.2	313.6								
51014291	57998089	65341135	66035016	73560041								
380	380	380	420	420								
1.59	1.47	1.35	1.46	1.34								
Actual values					Scenario							

(2) Scenario Setting by Model Sheet; Defining Equations

Scenarios are also set by defining the relationship of variables shown by equations and values of parameters.

GDP Share							
	Industry		%		SHIN	$CA	LN(TREND)
	Commercial		%		SHCM	$CA	LN(TREND)
	Public		%		SHPU	$CA	LN(TREND)
	Others		%		SHOT	$CA	LN(TREND)
	for ajustment to total 100 %				SHTL	=	SHIN+SHCM+SHPU+SHOT
GDP	GDP Growth rate		%	(External)	GR	=	**4.5**
	Total (Scenario)			(External)	GDP	=	lag1.GDP*(1+GR/100)
	Industry			(External)	GDPIN	=	GDP*(SHIN/SHTL)
	Commercial			(External)	GDPCM	=	GDP*(SHCM/SHTL)
	Public			(External)	GDPPU	=	GDP*(SHPU/SHTL)
	Others			(External)	GDPOT	=	GDP*(SHOT/SHTL)
CPI			1995=100		CPI	=	lag1.CPI*(1+INFL/100)
Inflation			%	(External)	INFL	=	**GR*1.2**
Price Scenario (Real Value Constant)							
	Industry		/kWh		PINEL	=	lag1.PINEL*(1+INFL/100)
	Residential		/kWh		PREEL	=	lag1.PREEL*(1+INFL/100)
	Commercial (Business)		/kWh		PCMEL	=	lag1.PCMEL*(1+INFL/100)
	Public		/kWh		PPUEL	=	lag1.PPUEL*(1+INFL/100)

Model Manual

for

Electric Power Demand Forecasting Models for Cambodia

By CHEW, Chong Siang

JICA Team

May 2022

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Notes

- This manual is based on data that can be collected at the current condition. As more data becomes available, the model can be flexibly expanded and improved in accuracy.
- The model has been simplified in its structure to make it easier for the novice to understand. This structure can be easily modified and rewritten to fit Cambodia's reality.

I. Explanation of Models

1. General

1.1 Concept of electric power demand forecasting model for Cambodia

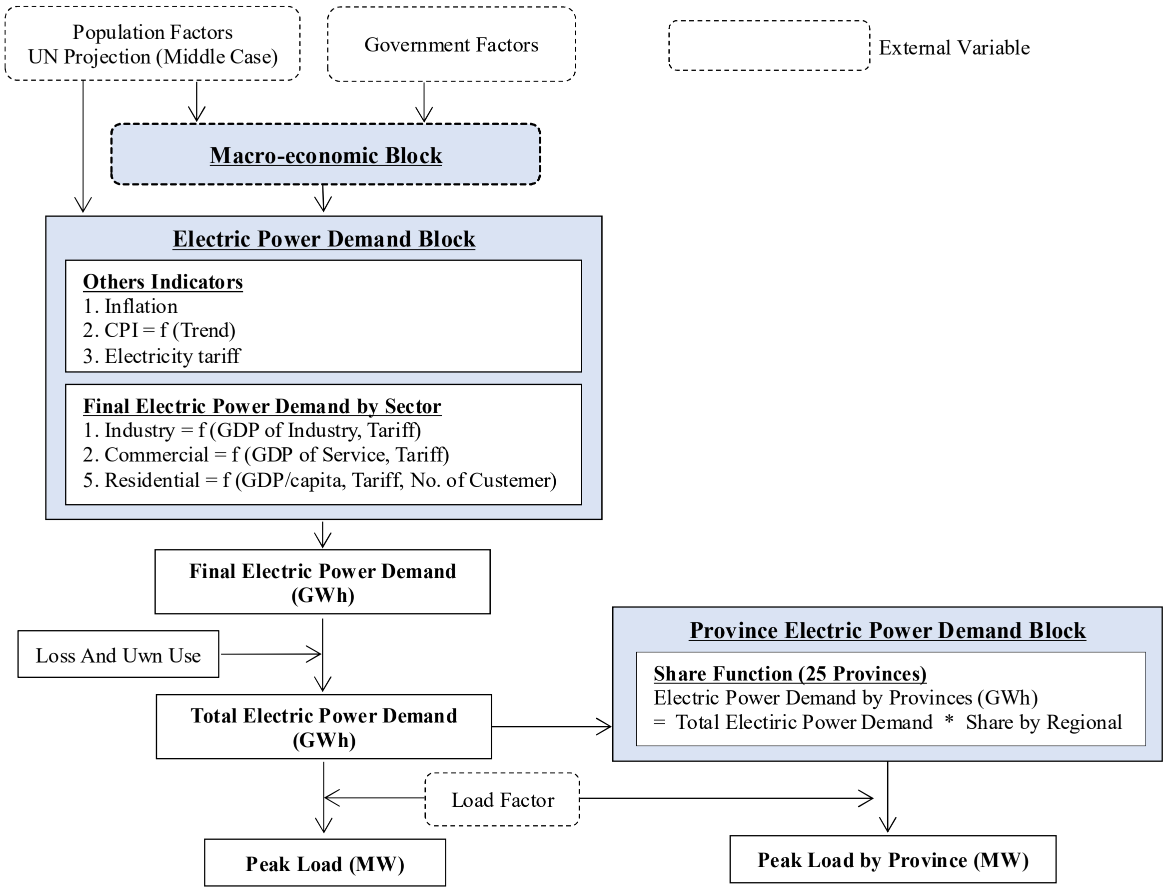
(1) Type of model and approach

This is an econometric model base on regression analysis method and applying various assumption. The macro indicator assumption like economic growth, population growth, price index and inflation are used as preconditions to reflect the macroeconomic policy of the Cambodian government.

(2) Schematic Diagram

The Electric power demand forecasting model consists of a macro-economic block, electric power demand block, and province electric power demand block as shown in Figure I-1. The model computes electric power demand by sector of the electric power demand block, using economic indices obtained from the macro-economic model block. The total electric power demand will divide by provinces by the historical ratio change in the province electric power demand block.

Figure I-1 Schematic Diagram of Electric Power Demand Forecasting Model



1.2 Code Name

Naming of code (abbreviations) is left to modeler's discretion. Generally, the first two characters will be using to create a code name. As a reference, an example is shown in Figure I-2. In this case, sector classification is the first two characters and energy classification are the second two characters, however, such kind of rule is basically free. The code must be easily recognizable and simple.

Figure I-2 An Example of Code Name

Items	Code Name
Population	POP
Gross domestic product	GDP
Agriculture, forestry, and fishing	AG
Industry	IN
Services	SE
Consumer prices Index	CPI
Electricity	EL
Price	P
Electricity consumption by sector	
Industry	INEL
Commercial	COEL
Residential	REEL

2. Calculation Process of Electricity Demand Forecasting Model

2.1 Macro-economic Block

In this case, macro indicators consist of three items, that is, (1) population, (2) GDP by sector and (3) consumer price index. In the electricity demand forecasting, former items described above are treated as external valuables in order to simulate the impact of price and GDP growth.

Notes:

Future extensions to the model will include sectoral additional data on electricity tariffs, number of customers, and electrification rates to improve the accuracy of the model. The current model will construct by framework with a limited data at the current condition.

(1) Macro Indicators (Assumptions)

Figure I-3 shows the system equations for macro-indicators (POP, GDPR, CPI and Inflation). Share of classified sectors (GDP.TLS) and each share of GDPR (GDP.AGS, GDP.INS, GDP.SES, and GDP.OTS) is not regression analysis. These equations are taken into consideration an economic structure change based on the historical trend. In case that we don't consider the structure change, we can fix the share or we can calculate the moving average. If we want to introduce structure change scenario, we can put our scenario into "Data" sheet directly.

In this case, the population and GDPR data are set in the "Data" sheet from 2000 until 2020. After 2020 until 2030, population growth rate is given as 1.4% and GDPR is given as 6.0% in the "Model" sheet.

Figure I-3 Macro-indicators ("Model" Sheet)

Macro Block							
	Total population			POP	=	lag1.POP*(1+1.4/100)	
GDP by share (Constant 2000)							
	Agriculture, forestry, and fish	%		GDP.AGS	$CA	LN(TREND)	
	Industry	%		GDP.INS	$CA	LN(TREND)	
	Services, etc.	%		GDP.SES	$CA	LN(TREND)	
	Others	%		GDP.OTS	$CA	LN(TREND)	
	Total	%		GDP.TLS	=	GDP.AGS+GDP.INS+GDP.SES+GDP.OTS	
GDP (Constant 2000)							
	GDP growth rate	%					
	Agriculture, forestry, and fish	KR Billion		AGR	=	GDPR*(GDP.AGS/GDP.TLS)	
	Industry	KR Billion		INR	=	GDPR*(GDP.INS/GDP.TLS)	
	Services, etc.	KR Billion		SER	=	GDPR*(GDP.SES/GDP.TLS)	
	Others	KR Billion		OTR	=	GDPR*(GDP.OTS/GDP.TLS)	
	Real GDP	KR Billion		GDPR	=	lag1.GDPR*(1+6/100)	

Notes:

lag1: Previous year data

LN: Logarithm

(2) Price Scenario (Assumptions)

Figure I-4 shows the price scenario in the "Model" sheet. Prices are up with inflation (real value constant) if the cells in "Data" sheet" are blank. In this case, inflation is given as 3% in the "Model" sheet. CPI will alternative the electricity tariff as a price scenario in this model. For future revision, please input the electricity tariff in the "Data" sheet and setting the price scenario by the sectoral electricity tariff (turn the red color to black).

Notes:

In "Model" sheet, if we turn the character to red color, simple-e will stop to make the calculation in that part.

Figure I-4 Price Scenario ("Model" Sheet)

Price Block						
	Inflation			INFL	=	3
	Consumer Price Index			CPI	=	lag1.CPI*(1+INFL/100)
Electricity Distribution - Weighted Average						
Domestic Tariff (residential)		Ush/kWh		ELP.RE	=	lag1.ELP.RE*(1+INFL/100)
Commercial Tariffs		Ush/kWh		ELP.COM	=	lag1.ELP.COM*(1+INFL/100)
Large Industrial Tariff		Ush/kWh		ELP.IN	=	lag1.ELP.IN*(1+INFL/100)

2.2 Electric Power Demand Block

Electric power demand block comprising of each sector creates the system equations by sector and calculates sectoral demand and the total. The demand function is estimated by regression analysis in each sectoral demand for industry (INEL), residential (REEL), commercial (CMEL, included the government/public sectors). The total demand (TLEL) is obtained by adding the sectoral demand after included the own use (OWN, consumption in power plat) and losses (LOSS, transmission and distribution).

(1) System Equations in Power Sector Block ("Model" sheet)

Figure I-5 shows the system equations in each demand sector. Basically, system equations by sector were created as the following functional relations.

1) Industry sector
   Electricity demand = f (GDP of industry, Price for industry)
2) Residential sector
   Number of customers = f (Electrification ratio)
   Electricity demand = f (Electricity consumption/Customer, Price for households, Number of customers, Previous year's demand)
3) Commercial sector
   Electricity demand = f (GDP of commercial, Price for commercial sector)

In this training, we will simplify the functions as figure I-5 because of the data on electricity rates, number of customers, and electrification rates were not collected. Please try to revise the model by above equations when your success to collect those data.

Own use and losses are set as assumption. Own use is given as 2.5% of final consumption by sector and losses is given as 6.0% annual growth. Total electricity demand will include the INEL, REEL, CMEL, OWN, and LOSS.

Figure I-5 System Equation in Electric Power Demand Block ("Model" Sheet)

Electric power Block							
Final comsumption by sector		FCEL	=	INEL+REEL+CMEL			
Industry		INEL	$CA,$DL	INR	lag1.INEL		
Residential		REEL	$CA,$DL	POP	Lag1.REEL	CPI	
Commercial		CMEL	$DL	SER	CPI	lag1.CMEL	
Own use in electricity, CHP and heat plants		OWN	=	FCEL*0.025			
Losses		LOSS	=	lag1.LOSS*(1+6/100)			
Export		EXEL	=	0			
Total Electricity Demand		TLEL	=	INEL+REEL+CMEL+OWN+LOSS+EXEL			

As an example, equations obtained by the regression analysis are as follows.

1) Industry sector

LN (INEL)= -3.5977 (-2.66) + 0.6038 (2.96) * LN (INR) + 0.7153 (8.06) * LN (LAG1.INEL)

Where, R square = 0.994

Durbin Watson ratio = 2.16

2) Residential sector

LN (REEL)= -47.068 (-2.16) + 5.3191 (2.16) * LN(POP) + 0.4344 (1.61) *LN(LAG1.REEL) -.007085(-0.394) *LN(CPI)

Where, R square = 0.995

Durbin Watson ratio = 2.09

3) Commercial sector

LN (CMEL)= -10.548 (-4.88) + 1.5977 (4.98) * LN(SER) - 0.0479 (-3.15) * LN(CPI) +0.3657 (2.89) * LN(LAG1.CMEL)

Where, R square = 0.998

Durbin Watson ratio = 2.73

Notes:

LAG1: Previous Year's Values

Values in ( ): t-value

(2) Peak Load (MW)

Peak load can be calculated by the following equation. The load factor is set as an assumption or scenario.

Peak Load = Total Electricity Demand / ((Load Factor/100) * 365 Day * 24 Hour)

2.3 Province Electric Power Demand Block

In this section, the electricity demand in province is distributed into 24 areas. Phnom Penh and Kandal province will combine together as one area because of the grid system.

(1) Share of Electric Power Demand by Regional

Finally, the electric power demand is distributed to each area by province using its historical trend (logarithmic trend). Figure I-6 shows the share estimation of each province and area. These equations are not due to regression analysis. We can change these definitions if we have a scenario and policy.

Figure I-6 Share of Electric Power Demand by Provinces (“Model” Sheet)

Regional by Share (%)								
Banteay Meanchey				BTCS	$CA	ln(TREND)		
Battambang				BTBS	$CA	ln(TREND)		
Kampong Cham				KGCS	$CA	ln(TREND)		
Kampong Chhnang				KGHS	$CA	ln(TREND)		
Kampong Speu				KPSS	$CA	ln(TREND)		
Kampong Thom				KTMS	$CA	ln(TREND)		
Kampot				KPTS	$CA	ln(TREND)		
Kohkong				KKGS	$CA	ln(TREND)		
Kratie				KRTS	$CA	ln(TREND)		
Mondulkiri				MDKS	$CA	ln(TREND)		
Phnom Penh / Kandal				PHNS	$CA	ln(TREND)		
Preah Vihear				PRIS	$CA	ln(TREND)		
Prey Veng				PRVS	$CA	ln(TREND)		
Pursat				PSTS	$CA	ln(TREND)		
Ratanakkiri				RTKS	$CA	ln(TREND)		
Siem Reap				SRPS	$CA	ln(TREND)		
Preah Sihanouk				SHVS	$CA	ln(TREND)		
Stung Treng				STRS	$CA	ln(TREND)		
Svay Rieng (Bavet)				SVRS	$CA	ln(TREND)		
Takeo				TKOS	$CA	ln(TREND)		
Oddar Meanchey				ODMS	$CA	ln(TREND)		
Kep				KEPS	$CA	ln(TREND)		
Pailin				PALS	$CA	ln(TREND)		
Tbong Khmum				TGKS	=	TLS-(BTCS+BTBS+KGCS+KGHS+KPSS+KTMS-		
Total	%			TLS	=	100		

(2) Electric Power Demand by Regional

Electric power demand by province and area are calculated by share.

Figure I-7 Electric Power Demand by Provinces (“Model” Sheet)

Electricty Demand by Provinces								
Banteay Meanchey				BTC	=	TLEL*BTCS/100		
Battambang				BTB	=	TLEL*BTBS/100		
Kampong Cham				KGC	=	TLEL*KGCS/100		
Kampong Chhnang				KGH	=	TLEL*KGHS/100		
Kampong Speu				KPS	=	TLEL*KPSS/100		
Kampong Thom				KTM	=	TLEL*KTMS/100		
Kampot				KPT	=	TLEL*KPTS/100		
Kohkong				KKG	=	TLEL*KKGS/100		
Kratie				KRT	=	TLEL*KRTS/100		
Mondulkiri				MDK	=	TLEL*MDKS/100		
Phnom Penh / Kandal				PHN	=	TLEL*PHNS/100		
Preah Vihear				PRI	=	TLEL*PRIS/100		
Prey Veng				PRV	=	TLEL*PRVS/100		
Pursat				PST	=	TLEL*PSTS/100		
Ratanakkiri				RTK	=	TLEL*RTKS/100		
Siem Reap				SRP	=	TLEL*SRPS/100		
Preah Sihanouk				SHV	=	TLEL*SHVS/100		
Stung Treng				STR	=	TLEL*STRS/100		
Svay Rieng (Bavet)				SVR	=	TLEL*SVRS/100		
Takeo				TKO	=	TLEL*TKOS/100		
Oddar Meanchey				ODM	=	TLEL*ODMS/100		
Kep				KEP	=	TLEL*KEPS/100		
Pailin				PAL	=	TLEL*PALS/100		
Tbong Khmum				TGK	=	TLEL*TGKS/100		
Total				TL	=	BTC+BTB+KGC+KGH+KPS+KTM+KPT+KKG+I		

II. Fundamentals for 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. Figure II-1 shows the examples of energy model (sub-model) and the objectives.

Figure II-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 express 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 stocks 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

Figure II-2 below shows the typical functional forms written in “Simple-E model sheet” as an example. In the Figure, Y (demand) is defined as internal (dependent) valuable, and X or Xi is external (independent) valuable (GNP and price etc.). Figure II-3 also shows typical demand function as an example.

Figure II-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)

Figure II-3 Example of typical flow type demand function

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

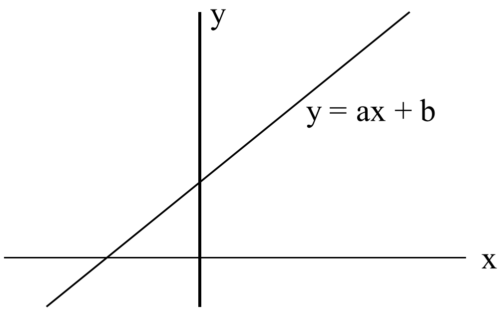
Y = Income Index
P = Price Index
D (-1) = Demand for previous year

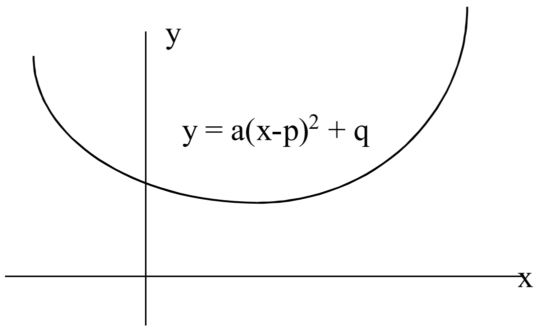
b = Income elasticity (short period)
c = Price elasticity (short period)
1-d =Time adjustment term
e = Technical improvement term
b/(1-d) = Long term Income elasticity
c/(1-d) = Long term Price elasticity

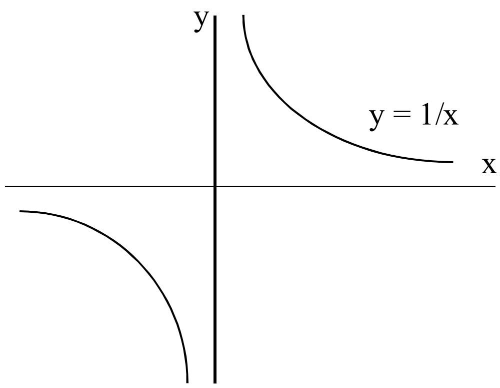
2. Determination of Demand Function

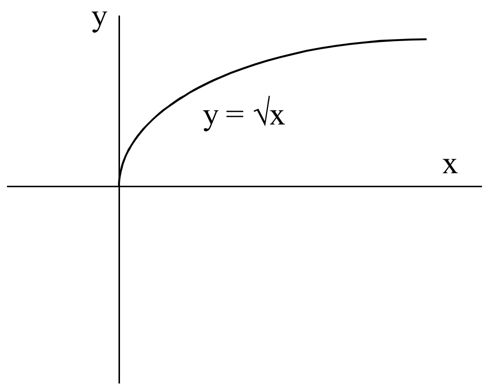
2.1 General Functional Forms

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)



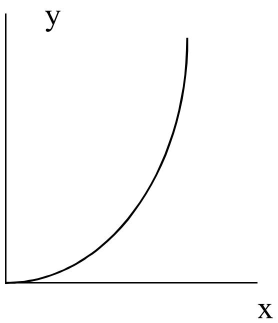




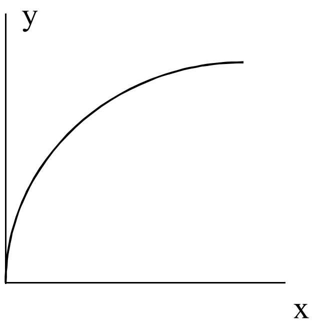


Power function $y = x^a$

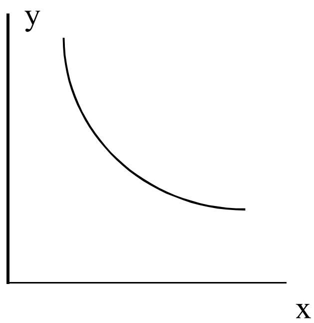
(1) $a > 1$



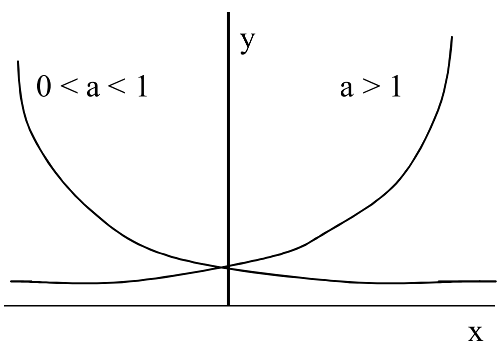
(2) $1 > a > 0$



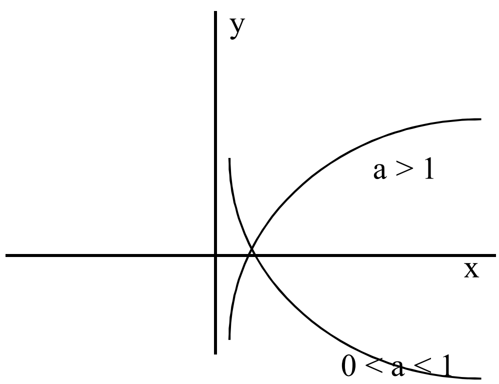
(3) $a < 1$



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

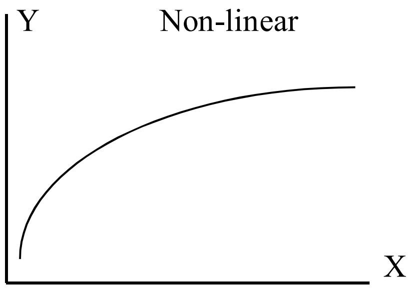


Logarithmic function $y = \log_a x$

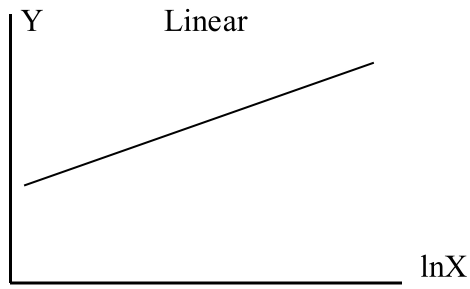


2.2 Linearization

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

2.3 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. Regression Analysis

3.1 Fitness of Equation by Regression Analysis

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

2) AR — Adjusted R-Square, $AR \le 1$, (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 Watson Statistics, $1 < DW < 3$
- $DW = 2$: No serial correlation
- $DW \rightarrow 0$: Positive correlation
- $DW \rightarrow 4$: Negative correlation

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

6) t-value	$\lvert t \rvert \geq 2$	: Significant
	$2 > \lvert t \rvert \geq 1$	: Admissible to use
	$\lvert t \rvert < 1$	: Insignificant
7) Rho	Coefficient of serial correlation, $\lvert Rho \rvert < 1$	
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, $\lvert YX \rvert < 1$	
12) XX	Correlation Coefficient between X's, $\lvert XX \rvert < 0.95$	

3.2 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, $Y = a + b*X$

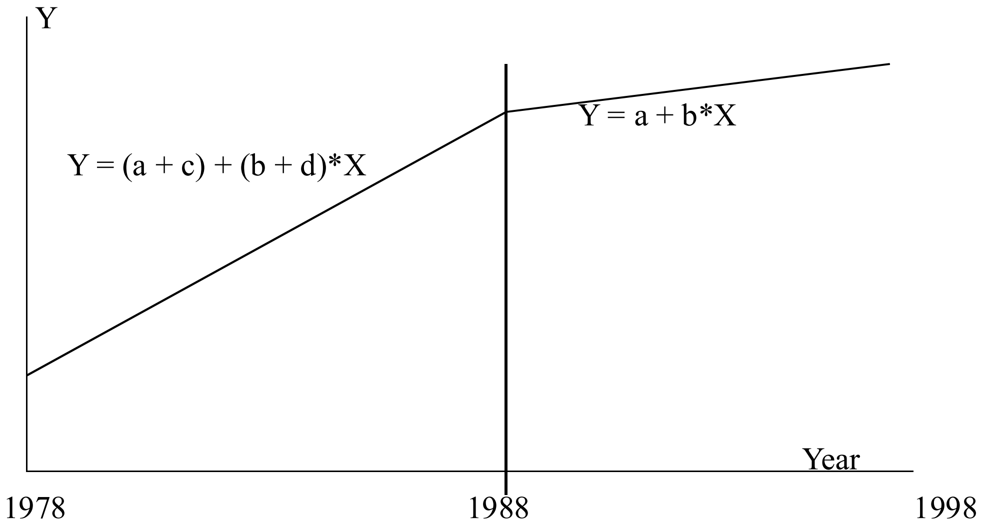
2) To consider structure change of demand function

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

(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.

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

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

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

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

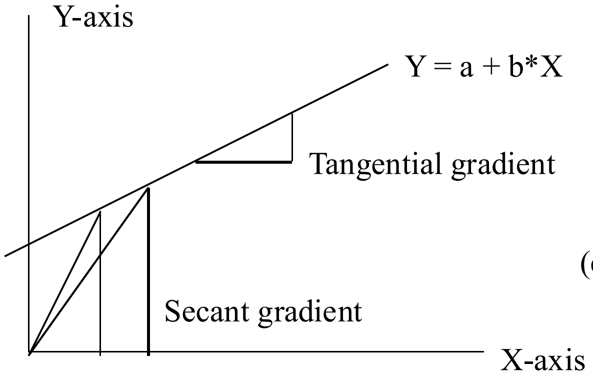
Definition of Elasticity (e)
$Y = f(X)$
$e = (dY/Y) / (dX/X) = (dY/dX) * (X/Y)$

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

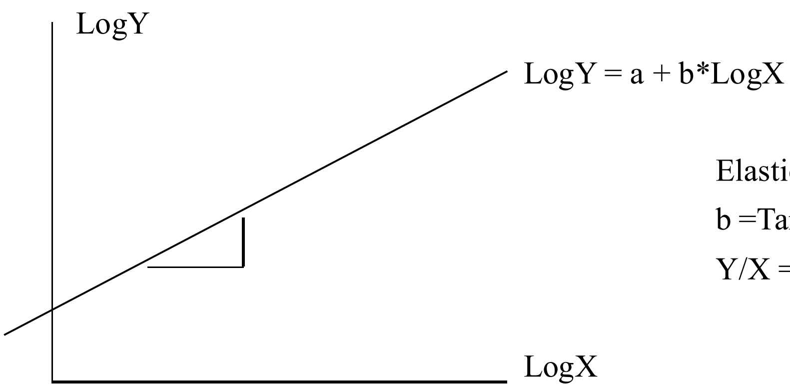
(e = increased function of X/Y)

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) $\text{LogY} = a + b \cdot \text{LogX} + c \cdot Z \cdot \text{LogX}$

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

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

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) LogY = a + b*LogX + c*logY(-1)

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

LogY = a/(1-c) + b/(1-c)*LogX

Boundary condition c = 0, LogY = a + b*LogX

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

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

6.3) LogY = a + b*LogX1 + c*logX2 + d*logY(-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)