Department of Energy Policy and Planning
Ministry of Energy and Mines
Lao People's Democratic Republic

Project for the Improvement of the Governance Mechanism for Sustainable Power Development Planning

Manuals for developing the PDP

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Chapter 1 Introduction

In the study 'Project for the Improvement of the Governance Mechanism for Sustainable Power Development Planning', technical assistance in the formulation of the PDP was implemented. In this booklet, the main tasks for the formulation of the PDP conducted in this study have been summarized as a manual.

The formulation work of the PDP is largely categorized into three factors: demand forecast, generation planning and transmission planning. As shown below, from the results of demand forecast and generation planning, (based on demand & supply calculation and system analysis) transmission planning is formulated.

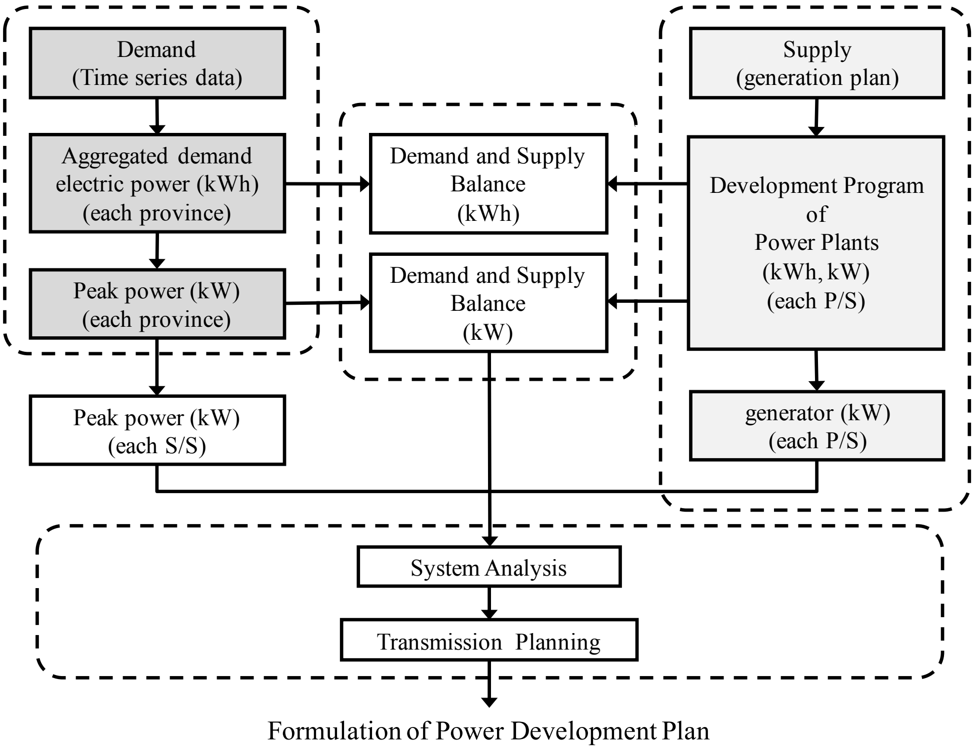


Figure 1-1 : formulation work of the PDP

In this study, the Study Team formulated demand forecast based on econometric methodology. From the result of this demand forecast and the generation plan by EDL (for PDP2012-2023), the Study Team conducted demand & supply calculation, based on which power system analysis by PSS/E was conducted and the transmission plan was formulated.

Therefore, in this manual, among the tasks necessary for PDP formulation, essential factors conducted in this study, demand forecast and power system analysis (including demand & supply calculation), are described.

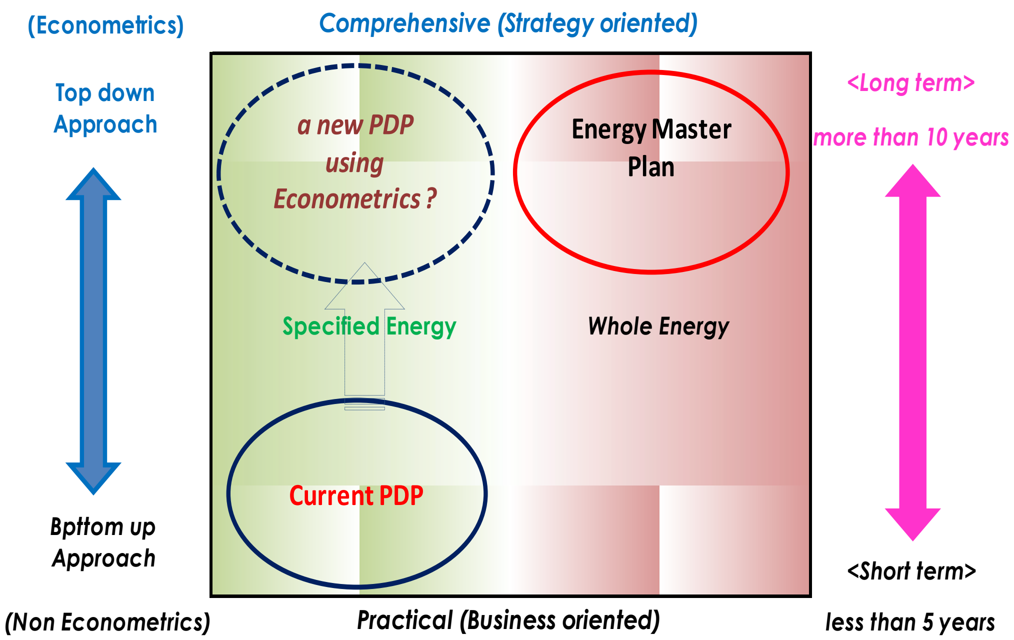
Chapter 2 Demand forecast

2.1 Outline of demand forecast

2.1.1 Econometric approach

Econometric approach is based on past actual data and economic theory. If you would like to estimate more appropriate figures and to properly measure the relationships of economy and energy, it would be better to consider policy options. But it requires a system consuming energy to develop to the advanced in some degree. At this moment, it seems a little too early. On the other hand, the time is coming up soon when Lao is taking off the undeveloped. That is why we propose that econometric approach should be introduced in the place of the current method, knowing the limitation of it.

It is excellent when evaluating the cost effectiveness on policy options, especially when formulating NPDP and/or Energy Master Plan.



(Source : Study Team)

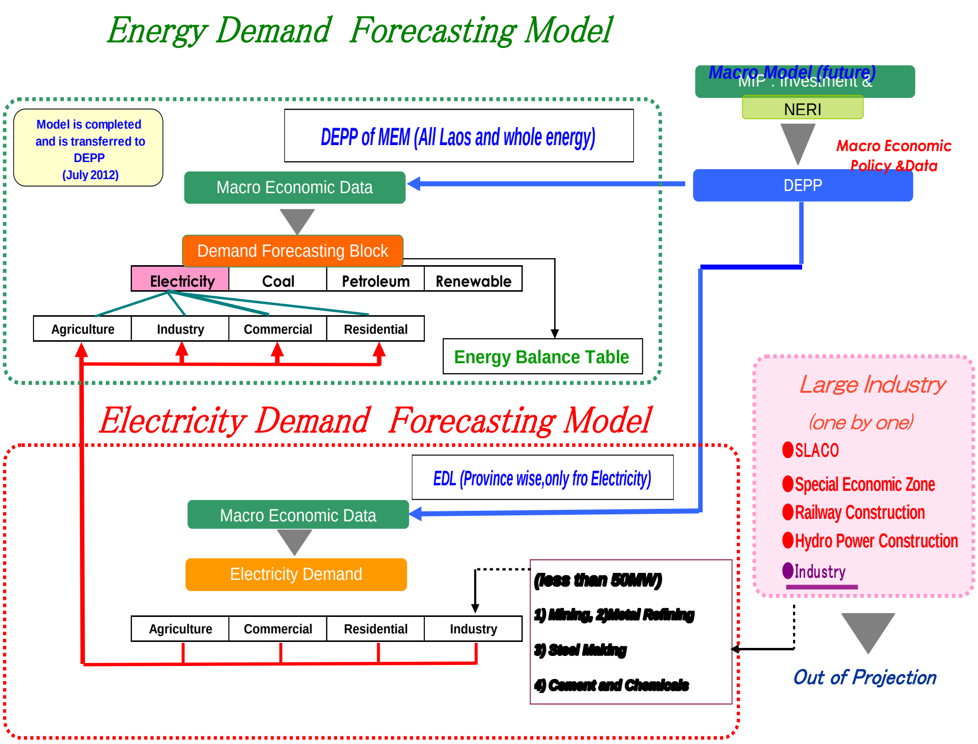
Figure 2-1 : Demarcation of various types of demand forecasting model

2.1.2 Large Industry

According to the PDP, the category of demand forecasting is categorized into two types, “Large Industry” and “others”: the former consists of gold/copper/zinc mining, non-ferrous metal refinery, and dam/railway construction. As most projects listed on PDP seem unrealistic and unconfirmed, we strongly recommend that such large industries should be excluded when estimating demand. In most advanced countries, they are not count one by one as demand to come true in future" If a project with relatively small size is realized, it is regarded as one of the aggregated demand estimated by econometric approach. The others should be dealt with outside forecasting in case they are implemented.

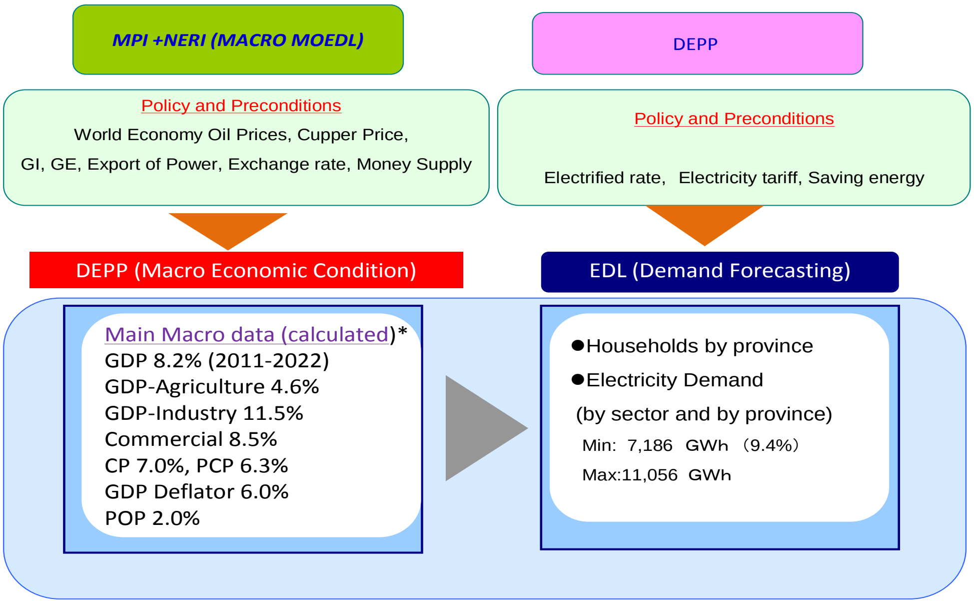
2.1.3 Model Structure and the flow of Input and Output

Electricity demand forecasting model for EDL is basically using the same economic conditions as Energy demand forecasting model for DEPP. In future, the economic data (preconditions) that will be estimated and well examined is supposed to be brought by NERI (MIP). On the other hand, the output data by province produced with the model is aggregated into a single demand (all Laos) and transferred to Energy demand forecasting model.

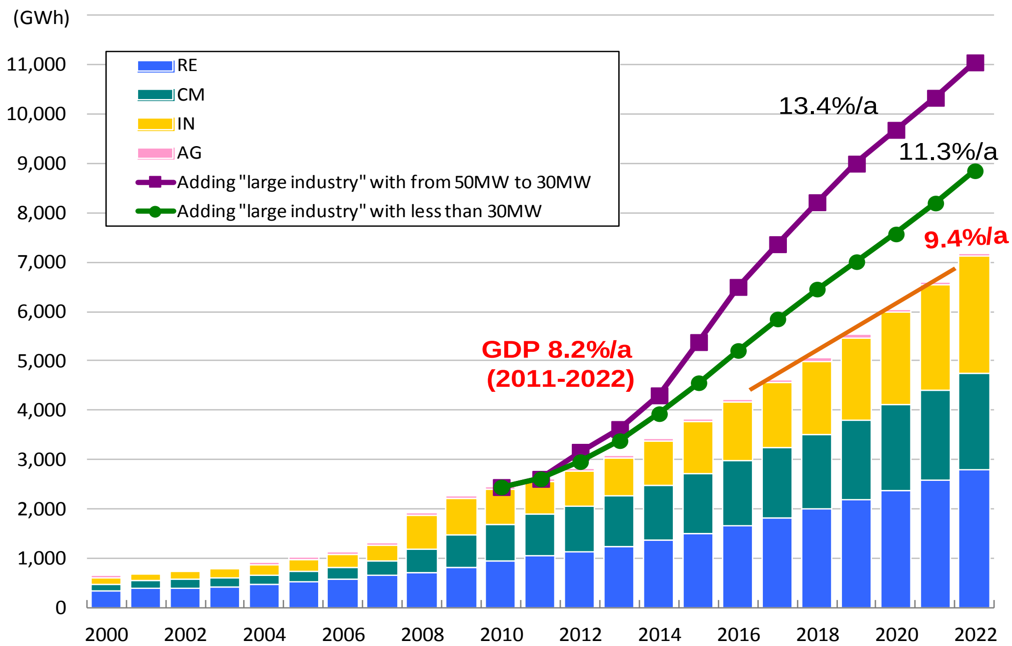


(Source : Study Team)

Figure 2-2 : Model Structure and the flow of Input data and Output data



* Default figures : they are estimated by IEEJ using a simple Macro model.



(Source : Study Team)

Figure 2-3 : Simulation results of "Default Case"

2.2 The method to operate Lao electricity demand model

2.2.1 Structure of Lao Electricity Demand Model

The Lao Electricity Model consists of 5 sectors, and each sector has 4 regions, e.g. Central-1, Central-2, North, and South regions. These 4 regions consist of 17 provinces as shown below.

1) Residential Sector

Central-1 region: Vientiane Capital, Huaphanh, Xiengkhuang, Vientiane Province
Central-2 region: Bolikahamxai, Khammouane, Savannakhet
North region: Phongsaly, Luangnamtha, Oudomxai, Bokeo, Luangprabang, Sayaboury (Xayaboury)
South region: Saravan, Sekong, Champasak, Attapeu

2) Commercial Sector

The regional division is the same as the Residential one.

3) Industrial Sector (excluding Large Industry)

The regional division is the same as the Residential one.

4) Large Industry Sector

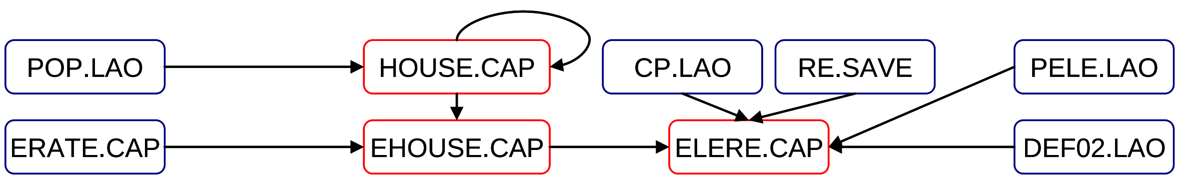
The regional division is the same as the Residential one.

5) Agricultural Sector

The regional division is the same as the Residential one.

2.2.2 The model flow example for Residential Sector in Vientiane Capital

The Electricity Demand of Residential Sector in Vientiane Capital is estimated by the following figures. The variables in blue circles are exogenous variables, while the variables in red circles are endogenous variables estimated or defined by those exogenous variables and the estimated variables.



(Source : Study Team)

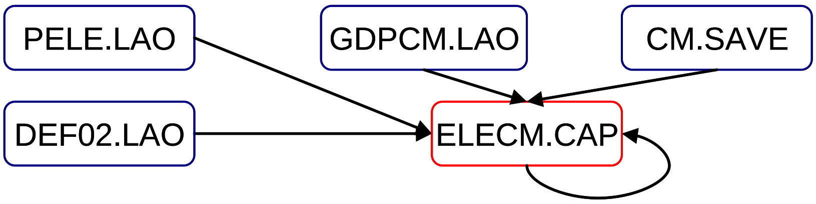
Figure 2-4 : The model flow example for Residential Sector in Vientiane Capital

The meanings of each variable are shown as below.
POP.CAP: Population in Vientiane Capita
ERATE.CAP: Residential electrified rate in Vientiane Capital
CP.LAO: Private consumption in Laos as a whole

RE.SAVE: Residential energy (electricity) saving ratio
HOUSE.CAP: The number of households in Vientiane Capital
EHOUSE.CAP: The number of electrified households in Vientiane Capital
PELE.LAO: Average Electricity Price in Laos as a whole
DEF02.LAO: GDP Deflator whose standard year is 2002
ELERE.CAP: Residential Electricity Demand in Vientiane Capital

2.2.3 The model flow example for Commercial Sector in Vientiane Capital

The Electricity Demand of Commercial Sector in Vientiane Capital is estimated by the following figures. The variables in the blue circles are exogenous variables, while the variable in the red circle is endogenous variable estimated by those exogenous variables.



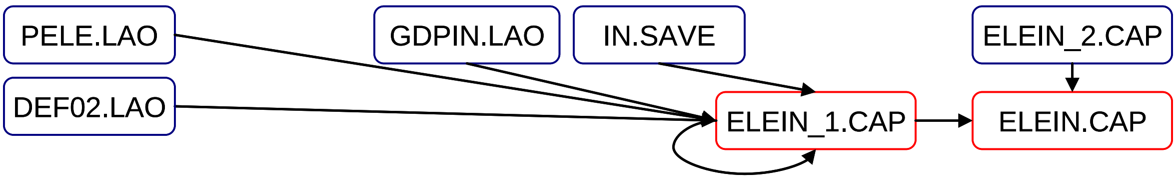
(Source : Study Team)

Figure 2-5 : The model flow example for Commercial Sector in Vientiane Capital

The meaning of each variable is shown as below.
PELE.LAO: Average Electricity Price in Laos as a whole
DEF02.LAO: GDP Deflator whose standard year is 2002
GDPCM.LAO: Real GDP in Commercial Sector
CM.SAVE: Commercial energy (electricity) saving ratio
ELECM.CAP: Commercial Electricity Demand in Vientiane Capital

2.2.4 The model flow example for Industrial Sector (including Large Industrial Sector) in Vientiane Capital

The Electricity Demand of Industrial Sector in Vientiane Capital is estimated by the following figures. The Large Industrial electricity demand is given as an exogenous variable since the growth of that is too fast to estimate by this regression model.



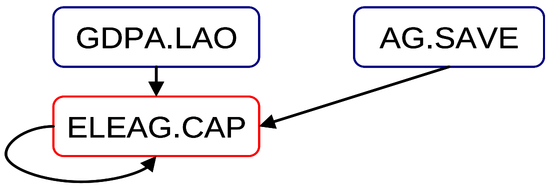
(Source : Study Team)

Figure 2-6 : The model flow example for Industrial Sector (including Large Industrial Sector) in Vientiane Capital

The meaning of each variable is shown as below.
PELE.LAO: Average Electricity Price in Laos as a whole
DEF02.LAO: GDP Deflator whose standard year is 2002
GDPIN.LAO: Real GDP in Industrial Sector
IN.SAVE: Industrial energy (electricity) saving ratio
ELEIN_1.CAP: Industrial (excluding Large Industry) Electricity Demand in Vientiane Capital
ELEIN_2.CAP: Large Industrial Electricity Demand in Vientiane Capital
ELEIN.CAP: Total Industrial Electricity Demand in Vientiane Capital

2.2.5 The model flow example for Agricultural Sector in Vientiane Capital

The Electricity Demand of Agricultural Sector in Vientiane Capital is estimated by the following figures. The variables in the blue circles are exogenous variables, while the variable in the red circle is estimated by those exogenous variables.



(Source : Study Team)

Figure 2-7 : The model flow example for Industrial Sector (including Large Industrial Sector) in Vientiane Capital

The meaning of each variable is shown as below.
GDPA.LAO: Real GDP in Agricultural Sector
AG.SAVE: Industrial energy (electricity) saving ratio
ELEAG.CAP: Agricultural Electricity Demand in Vientiane Capital

2.2.6 Rule for making Variable

The rules for making variables are shown in the following lists. For example, EHOUSE.PHO which means the number of electrified households in Phongsaly region is made by the rules of both Table. Macro Economic and Table. Regions.

Table 2-1 : Macro Economic

Variables	Meaning
POP.XXX	Population
HOUSE.XXX	Household
GDP.LAO	Real GDP
CP.LAO	Private Consumption
GDPCM.LAO	GDP Commercial (2002 Market Price)
GDPIN.LAO	GDP Industry (2002 Market Price)
GDPA.LAO	GDP Agriculture (2002 Market Price)
DEF02.LAO	GDP Deflator (2002=100)
PELE.LAO	Electricity Price

(Source : Study Team)

XXX needs to be replaced by variables of each province.

Table 2-2 : Electricity Demand

Variables	Meaning
ERATE.XXX	Electrified Rate
EHOUSE.XXX	Household Electrified
ELE.XXX	Electricity Demand
ELERE.XXX	Residential Electricity Demand
ELECM.XXX	Commercial Electricity Demand
ELEIN.XXX	Industrial Electricity Demand
ELEIN_1.XXX	Industrial Electricity Demand – 1
ELEIN_2.XXX	Industrial Electricity Demand – 2
ELELI.XXX	Electricity Demand of Large Industry
ELEAG.XXX	Agricultural Electricity Demand

(Source : Study Team)

XXX needs to be replaced by variables of each province.

Table 2-3 : Others

Variables	Meaning
RE_SAVE	Residential Energy Saving
CM_SAVE	Commercial Energy Saving
IN_SAVE	Industrial Energy Saving
AG_SAVE	Agricultural Energy Saving
DUMXX	Dummy variable

(Source : Study Team)

Table 2-4 : Regions

Variables	Meaning
LAO	LAO PDR
NOR	Northern Area
CEN_1	Central - 1 Area
CEN_2	Central -2 Area
SOU	Southern Area
CAP	Vientiane Cap.
PHO	Phongsaly
LNA	Luangnamtha
OUD	Oudomxay
BOK	Bokeo
LPR	Luangprabang
HUA	Huaphanh
XAY	Xayabury
XIE	Xiengkhuang
VIE	Vientiane
BOR	Borikhamxay
KHA	Khammuane
SAV	Savannakhet
SAR	Saravane
SEK	Sekong
CHA	Champasack
ATT	Attapeu
XSBSR	Xaysomboun

(Source : Study Team)

2.2.7 Details of Lao Electricity Demand Model

Details of Lao Electricity Demand Model are shown in this section. The model flow is mainly subject to the section 2.2.2, 2.2.3, 2.2.4, 2.2.5, and the meaning of the variables is understandable by the rule of the section 2.2.6. Definition equations are mainly used to integrate some provinces into Northern, Central-1, Central-2, Southern area or Laos as a whole by each sector or as a whole sector.

'---------- POPULATION ----------

'Number of Population in Future is Given

'Northern Area Total

POP.NOR=POP.PHO+POP.LNA+POP.OUD+POP.BOK+POP.LPR+POP.XAY

'Central-1 Area Total

POP.CEN_1=POP.CAP+POP.VIE+POP.HUA+POP.XIE+POP.XSBSR

'Central-2 Area Total

POP.CEN_2=POP.BOR+POP.KHA+POP.SAV

'Southern Area Total

POP.SOU=POP.SAR+POP.SEK+POP.CHA+POP.ATT

'Whole Country Total

POP.LAO=POP.NOR+POP.CEN_1+POP.CEN_2+POP.SOU

'

'---------- HOUSEHOLD ----------

'Vinetiane Cap.

HOUSE.CAP=-3064.61+.778508*(HOUSE.CAP(1))+5.53944*(POP.LAO)

' (-.12) (4.01) (.79)

' OLS (2001-2010) R^2=.891 SD= 3,104.58 DW ratio= 2.019

'Phongsaly Province

HOUSE.PHO=6056.19+.528209*(HOUSE.PHO(1))+1.28606*(POP.LAO)

' (1.51) (1.86) (1.35)

' OLS (2001-2010) R^2=.827 SD= 361.4105 DW ratio= 2.827

'Luang Namtha Province

HOUSE.LNA=-3219.24+.833909*(HOUSE.LNA(1))+1.39404*(POP.LAO)

' (-.45) (3.18) (.63)

' OLS (2001-2010) R^2=.901 SD= 737.7925 DW ratio= 1.944

'Oudomxai Province

HOUSE.OUD=-18365.4+.396203*(HOUSE.OUD(1))+7.69721*(POP.LAO)

' (-1.90) (1.55) (2.45)

' OLS (2001-2010) R^2=.904 SD= 1,073.79 DW ratio= 2.527

'Bokeo Province

HOUSE.BOK=-4011.72+.795196*(HOUSE.BOK(1))+1.68357*(POP.LAO)

' (-1.02) (5.23) (1.41)

' OLS (2001-2010) R^2=.958 SD= 439.1791 DW ratio= 1.289

'Luang Prabang Province

HOUSE.LPR=6493.10+.607528*(HOUSE.LPR(1))+3.63081*(POP.LAO)

' (.56) (1.81) (1.08)

' OLS (2001-2010) R^2=.761 SD= 1,384.93 DW ratio= 2.963

'Huaphanh Province

HOUSE.HUA=2940.21+.660487*(HOUSE.HUA(1))+2.09894*(POP.LAO)

' (1.22) (5.36) (2.32)

' OLS (2001-2010) R^2=.969 SD= 329.0257 DW ratio= 2.192

'Xayabury Province

HOUSE.XAY=1165.50+.841487*(HOUSE.XAY(1))+1.72044*(POP.LAO)

' (.12) (3.62) (.45)

' OLS (2001-2010) R^2=.934 SD= 1,101.84 DW ratio= 3.25

'Xiengkhuang Province

HOUSE.XIE=-3389.59+.577772*(HOUSE.XIE(1))+3.37035*(POP.LAO)+1183.77*(DUM07)-1228.53*(DUM04)

't-value (-.26) (1.14) (.64) (1.22) (-.89)

' OLS (2001-2010) R^2=.91 SD= 836.4923 DW ratio= 2.416

'Vientiane Province

HOUSE.VIE=6120.22+.916618*(HOUSE.VIE(1))+.305622*(POP.LAO)+1858.22*(DUM06)+2149.81*(DUM07)

't-value (.16) (3.44) (.03) (.67) (.78)

' OLS (2001-2010) R^2=.926 SD= 2,553.18 DW ratio= 1.572

'Borikhamxay Province

HOUSE.BOR=-5749.16+.814302*(HOUSE.BOR(1))+2.37237*(POP.LAO)

' (-.70) (3.78) (.89)

' OLS (2001-2010) R^2=.955 SD= 720.9441 DW ratio= 2.669

'Khammuane Province

HOUSE.KHA=-4006.50+.377185*(HOUSE.KHA(1))+7.39494*(POP.LAO)

' (-.31) (1.06) (1.40)

' OLS (2001-2010) R^2=.829 SD= 1,545.66 DW ratio= 1.977

'Savannakhet Province

HOUSE.SAV=10395.4+.573171*(HOUSE.SAV(1))+8.04391*(POP.LAO)

' (.41) (1.58) (.90)

' OLS (2001-2010) R^2=.714 SD= 3,551.16 DW ratio= 2.011

'Saravane Province

HOUSE.SAR=13652.9+.712606*(HOUSE.SAR(1))+.309687*(POP.LAO)+5687.93*(DUM02)+3712.70*(DUM09)

't-value (.62) (1.15) (.04) (1.86) (1.37)

' OLS (2001-2010) R^2=.606 SD= 2,092.04 DW ratio= 1.077

'Sekong Province

HOUSE.SEK=-2834.30+.378140*(HOUSE.SEK(1))+1.99273*(POP.LAO)

' (-.48) (.87) (1.13)

' OLS (2001-2010) R^2=.59 SD= 719.7693 DW ratio= 1.387

'Champassack Province

HOUSE.CHA=25407.0+.713754*(HOUSE.CHA(1))+.950164*(POP.LAO)

' (2.18) (2.79) (.21)

' OLS (2001-2010) R^2=.835 SD= 1,580.40 DW ratio= 2.408

'Attapeu Province

HOUSE.ATT=-2202.39+.807542*(HOUSE.ATT(1))+1.12707*(POP.LAO)

' (-.27) (2.13) (.43)

' OLS (2001-2010) R^2=.912 SD= 557.0575 DW ratio= 2.246

'

'Northern Area Total

HOUSE.NOR=HOUSE.PHO+HOUSE.LNA+HOUSE.OUD+HOUSE.BOK+HOUSE.LPR+HOUSE.XAY

'Central-1 Area Total

HOUSE.CEN_1=HOUSE.CAP+HOUSE.VIE+HOUSE.HUA+HOUSE.XIE+HOUSE.XSBSR

'Central-2 Area Total

HOUSE.CEN_2=HOUSE.BOR+HOUSE.KHA+HOUSE.SAV

'Southern Area Total

HOUSE.SOU=HOUSE.SAR+HOUSE.SEK+HOUSE.CHA+HOUSE.ATT

'Whole Country Total

HOUSE.LAO=HOUSE.NOR+HOUSE.CEN_1+HOUSE.CEN_2+HOUSE.SOU

'

'---------- HOUSEHOLD ELECTRIFIED ----------

'ERATE.XXX is Given

EHOUSE.CAP=HOUSE.CAP*ERATE.CAP/100

EHOUSE.PHO=HOUSE.PHO*ERATE.PHO/100

EHOUSE.LNA=HOUSE.LNA*ERATE.LNA/100

EHOUSE.OUD=HOUSE.OUD*ERATE.OUD/100

EHOUSE.BOK=HOUSE.BOK*ERATE.BOK/100

EHOUSE.LPR=HOUSE.LPR*ERATE.LPR/100

EHOUSE.HUA=HOUSE.HUA*ERATE.HUA/100

EHOUSE.XAY=HOUSE.XAY*ERATE.XAY/100

EHOUSE.XIE=HOUSE.XIE*ERATE.XIE/100

EHOUSE.VIE=HOUSE.VIE*ERATE.VIE/100

EHOUSE.BOR=HOUSE.BOR*ERATE.BOR/100

EHOUSE.KHA=HOUSE.KHA*ERATE.KHA/100

EHOUSE.SAV=HOUSE.SAV*ERATE.SAV/100

EHOUSE.SAR=HOUSE.SAR*ERATE.SAR/100

EHOUSE.SEK=HOUSE.SEK*ERATE.SEK/100

EHOUSE.CHA=HOUSE.CHA*ERATE.CHA/100

EHOUSE.ATT=HOUSE.ATT*ERATE.ATT/100

'

''Northern Area Total

EHOUSE.NOR=EHOUSE.PHO+EHOUSE.LNA+EHOUSE.OUD+EHOUSE.BOK+EHOUSE.LPR+EHOUSE.XAY

''Central-1 Area Total

EHOUSE.CEN_1=EHOUSE.CAP+EHOUSE.VIE+EHOUSE.HUA+EHOUSE.XIE

''Central-2 Area Total

EHOUSE.CEN_2=EHOUSE.BOR+EHOUSE.KHA+EHOUSE.SAV

''Southern Area Total

EHOUSE.SOU=EHOUSE.SAR+EHOUSE.SEK+EHOUSE.CHA+EHOUSE.ATT

''Whole Country Total

EHOUSE.LAO=EHOUSE.NOR+EHOUSE.CEN_1+EHOUSE.CEN_2+EHOUSE.SOU

'

'---------- RESIDENTIAL SECTOR ----------

'Vinetiane Cap.

ELERE.CAP=(1-RE.SAVE)*(EHOUSE.CAP*(1.28284+.404630*(ELERE.CAP(1)/EHOUSE.CAP(1))+.0000511*(CP.LAO)-.221681*(PELE.LAO/DEF02.LAO)+.091908*(DUM07)))

't-value (1.10) (1.14) (2.63) (-1.37) (1.26)

' OLS (2002-2008) R^2=.914 SD= .058319 DW ratio= 1.832

'Phongsaly Province

ELERE.PHO=(1-RE.SAVE)*(EHOUSE.PHO*(-.083410+.838773*(ELERE.PHO(1)/EHOUSE.PHO(1))+.0000084*(CP.LAO)-.013467*(PELE.LAO/DEF02.LAO)+.148634*(DUM08)))

't-value (-.98) (6.84) (1.79) (-.94) (7.56)

' OLS (2001-2010) R^2=.984 SD= .014822 DW ratio= 2.063

'Luang Namtha Province

ELERE.LNA=(1-RE.SAVE)*(EHOUSE.LNA*(-.150368+.517976*(ELERE.LNA(1)/EHOUSE.LNA(1))+.0000246*(CP.LAO)-.060616*(PELE.LAO/DEF02.LAO)+.084964*(DUM09)))

't-value (-.31) (.91) (.79) (-.74) (.92)

' OLS (2001-2010) R^2=.792 SD= .078274 DW ratio= 1.56

'Oudomxai Province

ELERE.OUD=(1-RE.SAVE)*(EHOUSE.OUD*(.054493+.237888*(ELERE.OUD(1)/EHOUSE.OUD(1))+.0000122*(GDP.LAO)+.247213*(DUM03)-.397279*(DUM04)))

't-value (.13) (.56) (.58) (1.03) (-1.41)

' OLS (2001-2010) R^2=.314 SD= .184469 DW ratio= 2.043

'Bokeo Province

ELERE.BOK=(1-RE.SAVE)*(EHOUSE.BOK*(.255808+.422859*(ELERE.BOK(1)/EHOUSE.BOK(1))+.0000157*(CP.LAO)-.040699*(PELE.LAO/DEF02.LAO)+.107690*(DUM03)))

't-value (.62) (3.65) (1.22) (-.87) (2.49)

' OLS (2001-2008) R^2=.847 SD= .035559 DW ratio= 3.289

'Luang Prabang Province

ELERE.LPR=(1-RE.SAVE)*(EHOUSE.LPR*(.041522+.558884*(ELERE.LPR(1)/EHOUSE.LPR(1))+.0000212*(CP.LAO)-.026209*(PELE.LAO/DEF02.LAO)-.057077*(DUM04)+.124642*(DUM06)))

't-value (.03) (.79) (1.60) (-.12) (-.63) (1.16)

' OLS (2003-2010) R^2=.743 SD= .042139 DW ratio= 1.89

'Huaphanh Province

ELERE.HUA=(1-RE.SAVE)*(EHOUSE.HUA*(.418077+.119916*(ELERE.HUA(1)/EHOUSE.HUA(1))+.0000133*(CP.LAO)-.078890*(PELE.LAO/DEF02.LAO)+.097914*(DUM02)+.009439*(DUM03)))

't-value (19.79) (9.19) (13.23) (-22.60) (25.36) (2.56)

' OLS (2001-2008) R^2=.996 SD= .002302 DW ratio= 3.249

'Xayabury Province

ELERE.XAY=(1-RE.SAVE)*(EHOUSE.XAY*(.641379+.412148*(ELERE.XAY(1)/EHOUSE.XAY(1))+.0000087*(CP.LAO)-.138365*(PELE.LAO/DEF02.LAO)-.126249*(DUM09)))

't-value (1.88) (3.47) (.93) (-2.03) (-2.53)

' OLS (2002-2010) R^2=.864 SD= .042548 DW ratio= 2.37

'Xiengkhuang Province

ELERE.XIE=(1-RE.SAVE)*(EHOUSE.XIE*(-.222722+.606490*(ELERE.XIE(1)/EHOUSE.XIE(1))+.0000219*(CP.LAO)-.437049*(DUM05)+.490404*(DUM06)))

't-value (-.34) (1.56) (.52) (-2.62) (3.00)

' OLS (2001-2010) R^2=.743 SD= .142828 DW ratio= 1.501

'Vientiane Province

ELERE.VIE=(1-RE.SAVE)*(EHOUSE.VIE*(.058473+.568996*(ELERE.VIE(1)/EHOUSE.VIE(1))+.0000193*(CP.LAO)+.083855*(DUM05)-.160103*(DUM07)))

't-value (.16) (1.40) (1.64) (.93) (-1.52)

' OLS (2002-2010) R^2=.339 SD= .083654 DW ratio= 2.612

'Borikhamxay Province

ELERE.BOR=(1-RE.SAVE)*(EHOUSE.BOR*(-.011344+.440652*(ELERE.BOR(1)/EHOUSE.BOR(1))+.0000285*(CP.LAO)-.004781*(PELE.LAO/DEF02.LAO)+.024886*(DUM05)))

't-value (-.03) (1.22) (1.79) (-.06) (.30)

' OLS (2001-2010) R^2=.692 SD= .071533 DW ratio= 2.105

'Khammuane Province

ELERE.KHA=(1-RE.SAVE)*(EHOUSE.KHA*(.851715+.406203*(ELERE.KHA(1)/EHOUSE.KHA(1))+.0000098*(CP.LAO)-.133251*(PELE.LAO/DEF02.LAO)+.100208*(DUM06)-.111140*(DUM08)-.114791*(DUM09)))

't-value (.65) (.53) (.43) (-1.02) (.54) (-.58) (-.77)

' OLS (2001-2010) R^2=. SD= .117223 DW ratio= 2.014

'Savannakhet Province

ELERE.SAV=(1-RE.SAVE)*(EHOUSE.SAV*(.412556+.815265*(ELERE.SAV(1)/EHOUSE.SAV(1))+.0000068*(CP.LAO)-.109067*(PELE.LAO/DEF02.LAO)))

't-value (.83) (1.35) (.58) (-.94)

' OLS (2003-2010) R^2=.121 SD= .058431 DW ratio= 2.449

'Saravane Province

ELERE.SAR=(1-RE.SAVE)*(EHOUSE.SAR*(.195646+.535612*(ELERE.SAR(1)/EHOUSE.SAR(1))+.0000058*(CP.LAO)-.142480*(DUM09)))

't-value (.29) (.93) (.31) (-2.26)

' OLS (2001-2010) R^2=.48 SD= .049944 DW ratio= 1.753

'Sekong Province

ELERE.SEK=(1-RE.SAVE)*(EHOUSE.SEK*(.282415+.507839*(ELERE.SEK(1)/EHOUSE.SEK(1))+.0000153*(CP.LAO)-.122918*(PELE.LAO/DEF02.LAO)+.524202*(DUM07)+.386036*(DUM08))) 't-value (.27) (1.98) (.50) (-.48) (3.62) (2.57)

' OLS (2002-2010) R^2=.906 SD= .118955 DW ratio= 1.271

'Champassack Province

ELERE.CHA=(1-RE.SAVE)*(EHOUSE.CHA*(.300099+.627892*(ELERE.CHA(1)/EHOUSE.CHA(1))+.0000129*(CP.LAO)-.053910*(PELE.LAO/DEF02.LAO)))

't-value (.42) (1.59) (1.00) (-.78)

' OLS (2001-2010) R^2=.244 SD= .064263 DW ratio= 2.142

'Attapeu Province

ELERE.ATT=(1-RE.SAVE)*(EHOUSE.ATT*(.519446+.732643*(ELERE.ATT(1)/EHOUSE.ATT(1))+.0000118*(CP.LAO)-.161957*(PELE.LAO/DEF02.LAO)-.092438*(DUM02)))

't-value (.33) (1.53) (.14) (-.49) (-.23)

' OLS (2001-2010) R^2=.477 SD= .325850 DW ratio= 1.445

'

' Residential Sector by Region

ELERE.NOR=ELERE.PHO+ELERE.LNA+ELERE.OUD+ELERE.BOK+ELERE.LPR+ELERE.XAY

ELERE.CEN_1=ELERE.CAP+ELERE.VIE+ELERE.HUA+ELERE.XIE

ELERE.CEN_2=ELERE.BOR+ELERE.KHA+ELERE.SAV

ELERE.SOU=ELERE.SAR+ELERE.SEK+ELERE.CHA+ELERE.ATT

'Whole Country Total

ELERE.LAO=ELERE.NOR+ELERE.CEN_1+ELERE.CEN_2+ELERE.SOU

'

'---------- COMMERCIAL SECTOR ----------

'Vinetiane Cap.

ELECM.CAP=(1-CM.SAVE)*(740.857+.368068*(ELECM.CAP(1))+12.3714*(GDPCM.LAO)-5725.04*(PELE.LAO/DEF02.LAO))

't-value (.01) (.87) (1.96) (-.43)

' OLS (2001-2010) R^2=.911 SD= 13,527.6 DW ratio= 2.162

'Phongsaly Province

ELECM.PHO=(1-CM.SAVE)*(-86.4844+.313046*(ELECM.PHO(1))+.084738*(GDPCM.LAO)-159.481*(PELE.LAO/DEF02.LAO))

't-value (-.18) (1.03) (2.48) (-1.28)

' OLS (2001-2010) R^2=.842 SD= 128.3960 DW ratio= 2.22

'Luang Namtha Province

ELECM.LNA=(1-CM.SAVE)*(-1829.33+.414121*(ELECM.LNA(1))+1.84246*(GDPCM.LAO)-3528.46*(PELE.LAO/DEF02.LAO))

't-value (-.21) (1.38) (2.77) (-1.53)

' OLS (2001-2010) R^2=.897 SD= 2,345.38 DW ratio= 2.499

'Oudomxai Province

ELECM.OUD=(1-CM.SAVE)*(-2199.87+.744572*(ELECM.OUD(1))+.340332*(GDPCM.LAO)-9.92771*(PELE.LAO/DEF02.LAO))

't-value (-.44) (.53) (.49) (-.01)
' OLS (2001-2010) R^2=.831 SD= 755.3640 DW ratio= 1.334

'Bokeo Province

ELECM.BOK=(1-CM.SAVE)*(-422.755+.482902*(ELECM.BOK(1))+.342649*(GDPCM.LAO)-402.022*(PELE.LAO/DEF02.LAO))

't-value (-.70) (1.38) (2.42) (-2.17)
' OLS (2001-2008) R^2=.978 SD= 149.4571 DW ratio= 2.657

'Luang Prabang Province

ELECM.LPR=(1-CM.SAVE)*(-945.379+.819817*(ELECM.LPR(1))+.768758*(GDPCM.LAO)-670.749*(PELE.LAO/DEF02.LAO))

't-value (-.36) (2.58) (1.27) (-1.02)
' OLS (2001-2009) R^2=.982 SD= 666.5393 DW ratio= 2.583

'Huaphanh ProvinceELECM.HUA=(1-CM.SAVE)*(-162.964+.464096*(ELECM.HUA(1))+.208545*(GDPCM.LAO)-250.151*(PELE.LAO/DEF02.LAO)+226.733*(DUM05))

't-value (-.38) (1.00) (1.61) (-2.02) (1.61)
' OLS (2001-2010) R^2=.989 SD= 89.1126 DW ratio= 2.396

'Xayabury Province

ELECM.XAY=(1-CM.SAVE)*(-5044.32+.218038*(ELECM.XAY(1))+.806980*(GDPCM.LAO)-25.4426*(PELE.LAO/DEF02.LAO)-441.007*(DUM08))

't-value (-2.16) (.42) (1.93) (-.11) (-1.99)
' OLS (2001-2009) R^2=.992 SD= 183.1209 DW ratio= 1.165

'Xiengkhuang Province

ELECM.XIE=(1-CM.SAVE)*(-3802.59+.095111*(ELECM.XIE(1))+.685905*(GDPCM.LAO)-236.687*(PELE.LAO/DEF02.LAO))

't-value (-2.27) (.15) (1.77) (-.60)
' OLS (2001-2008) R^2=.981 SD= 188.8455 DW ratio= 1.576

'Vientiane Province

ELECM.VIE=(1-CM.SAVE)*(1504.50+.316433*(ELECM.VIE(1))+2.32879*(GDPCM.LAO)-2855.64*(PELE.LAO/DEF02.LAO))

't-value (.17) (.50) (1.55) (-1.39)
' OLS (2001-2007) R^2=.82 SD= 2,024.06 DW ratio= 2.045

'Borikhamxay Province

ELECM.BOR=(1-CM.SAVE)*(-1363.10+.272387*(ELECM.BOR(1))+.543639*(GDPCM.LAO)-210.979*(PELE.LAO/DEF02.LAO)-166.030*(DUM02)+233.847*(DUM05))

't-value (-1.84) (.69) (2.12) (-1.91) (-2.90) (4.05)
' OLS (2001-2008) R^2=.999 SD= 42.3661 DW ratio= 2.796

'Khammuane Province

ELECM.KHA=(1-CM.SAVE)*(6655.66+.180449*(ELECM.KHA(1))+2.38882*(GDPCM.LAO)-5003.20*(PELE.LAO/DEF02.LAO)) 't-value (.54) (.51) (2.30) (-1.43)

' OLS (2001-2010) R^2=.832 SD= 3,353.62 DW ratio= 1.425

'Savannakhet Province

ELECM.SAV=(1-CM.SAVE)*(-8889.73+.654431*(ELECM.SAV(1))+2.14975*(GDPCM.LAO)-690.957 *(PELE.LAO/DEF02.LAO)-4942.20*(DUM08))

't-value (-.29) (1.40) (1.29) (-.10) (-1.31)

' OLS (2002-2010) R^2=.896 SD= 3,154.17 DW ratio= .867

'Saravane Province

ELECM.SAR=(1-CM.SAVE)*(470.936+.594087*(ELECM.SAR(1))+.196845*(GDPCM.LAO)-249.494 *(PELE.LAO/DEF02.LAO)+3270.50*(DUM08))

't-value (.29) (2.94) (1.37) (-.60) (5.26)

' OLS (2001-2010) R^2=.943 SD= 442.2650 DW ratio= 1.817

'Sekong Province

ELECM.SEK=(1-CM.SAVE)*(-552.202+.431223*(ELECM.SEK(1))+.305726*(GDPCM.LAO)-500.169 *(PELE.LAO/DEF02.LAO))

't-value (-.56) (1.62) (3.17) (-1.85)

' OLS (2001-2010) R^2=.953 SD= 261.4342 DW ratio= 2.652

'Champassack Province

ELECM.CHA=(1-CM.SAVE)*(-2941.99+.921655*(ELECM.CHA(1))+1.05712*(GDPCM.LAO)-944.98 1*(PELE.LAO/DEF02.LAO)-2011.20*(DUM08))

't-value (-.39) (1.96) (.95) (-.45) (-.74)

' OLS (2001-2010) R^2=.932 SD= 2,062.57 DW ratio= 1.854

'Attapeu Province

ELECM.ATT=(1-CM.SAVE)*(-558.141+.370469*(ELECM.ATT(1))+.481793*(GDPCM.LAO)-882.165 *(PELE.LAO/DEF02.LAO))

't-value (-.39) (1.37) (3.34) (-2.11)

' OLS (2001-2010) R^2=.953 SD= 390.0880 DW ratio= 2.236

'

' Commercial Sector by Region

ELECM.NOR=ELECM.PHO+ELECM.LNA+ELECM.OUD+ELECM.BOK+ELECM.LPR+ELECM.XA Y

ELECM.CEN_1=ELECM.CAP+ELECM.VIE+ELECM.HUA+ELECM.XIE

ELECM.CEN_2=ELECM.BOR+ELECM.KHA+ELECM.SAV

ELECM.SOU=ELECM.SAR+ELECM.SEK+ELECM.CHA+ELECM.ATT

'Whole Country Total

ELECM.LAO=ELECM.NOR+ELECM.CEN_1+ELECM.CEN_2+ELECM.SOU

'

'---------- INDUSTRIAL SECTOR (Except Large Industry) ----------

'Vinetiane Cap.

ELEIN_1.CAP=(1-IN.SAVE)*(-15007.3+.548437*(ELEIN_1.CAP(1))+28.1549*(GDPIN.LAO)-6312.2

5*(PELE.LAO/DEF02.LAO)-14004.7*(DUM03)-14753.1*(DUM07))
't-value (-.23) (.95) (1.37) (-.34) (-.72) (-.73)
' OLS (2001-2010) R^2=.933 SD= 17,775.8 DW ratio= 2.457

'Phongsaly Province

ELEIN_1.PHO=(1-IN.SAVE)*(23.5134+.354895*(ELEIN_1.PHO(1))+.041227*(GDPIN.LAO)-38.5209*(PELE.LAO/DEF02.LAO))
't-value (.14) (.95) (1.86) (-.85)
' OLS (2001-2010) R^2=.764 SD= 47.0834 DW ratio= 2.465

'Luang Namtha Province

ELEIN_1.LNA=(1-IN.SAVE)*(-29.0498+.902042*(ELEIN_1.LNA(1))+.072113*(GDPIN.LAO)-48.0613*(PELE.LAO/DEF02.LAO)+504.323*(DUM06)-520.858*(DUM07))
't-value (-.19) (3.38) (2.15) (-1.07) (8.01) (-4.25)
' OLS (2001-2010) R^2=.98 SD= 42.4816 DW ratio= 2.348

'Oudomxai Province

ELEIN_1.OUD=(1-IN.SAVE)*(1106.17+.303964*(ELEIN_1.OUD(1))+.205797*(GDPIN.LAO)-379.902*(PELE.LAO/DEF02.LAO))
't-value (1.07) (.91) (1.84) (-1.45)
' OLS (2002-2010) R^2=.948 SD= 118.1608 DW ratio= 2.741

'Bokeo Province

ELEIN_1.BOK=(1-IN.SAVE)*(-534.060+.133259*(ELEIN_1.BOK(1))+.376646*(GDPIN.LAO)-82.4610*(PELE.LAO/DEF02.LAO)+381.562*(DUM09))
't-value (-2.43) (.84) (5.81) (-1.44) (5.64)
' OLS (2001-2010) R^2=.992 SD= 57.3398 DW ratio= 3.018

'Luang Prabang Province

ELEIN_1.LPR=(1-IN.SAVE)*(850.448+.469850*(ELEIN_1.LPR(1))+1.76075*(GDPIN.LAO)-1288.26*(PELE.LAO/DEF02.LAO))
't-value (.19) (1.62) (2.14) (-.96)
' OLS (2001-2010) R^2=.922 SD= 1,278.21 DW ratio= .858

'Huaphanh Province

ELEIN_1.HUA=(1-IN.SAVE)*(833.984+.808910*(ELEIN_1.HUA(1))+.006080*(GDPIN.LAO)-258.926*(PELE.LAO/DEF02.LAO))
't-value (.75) (1.11) (.18) (-.86)
' OLS (2005-2010) R^2=.386 SD= 32.4795 DW ratio= 2.575

'Xayabury Province

ELEIN_1.XAY=(1-IN.SAVE)*(1715.12+.448885*(ELEIN_1.XAY(1))+1.23306*(GDPIN.LAO)-920.880*(PELE.LAO/DEF02.LAO)-1179.03*(DUM03))
't-value (.40) (1.65) (2.41) (-.77) (-2.13)
' OLS (2002-2010) R^2=.986 SD= 407.5687 DW ratio= 2.021

'Xiengkhuang Province

ELEIN_1.XIE=(1-IN.SAVE)*(570.444+.752986*(ELEIN_1.XIE(1))+.013144*(GDPIN.LAO))

' (.62) (2.82) (.05)

' OLS (2001-2010) R^2=.579 SD= 872.4586 DW ratio= 1.352

'Vientiane Province

ELEIN_1.VIE=(1-IN.SAVE)*(39709.7+.306716*(ELEIN_1.VIE(1))+1.68418*(GDPIN.LAO)-2922.95*(PELE.LAO/DEF02.LAO))

't-value (.74) (1.22) (.48) (-.23)

' OLS (2002-2010) R^2=.418 SD= 6,199.93 DW ratio= 3.107

'Borikhamxay Province

ELEIN_1.BOR=(1-IN.SAVE)*(3414.35+.197198*(ELEIN_1.BOR(1))+3.35539*(GDPIN.LAO)-2277.49 *(PELE.LAO/DEF02.LAO)+2915.29*(DUM04))

't-value (.15) (.55) (2.14) (-.40) (.93)

' OLS (2002-2010) R^2=.861 SD= 2,184.60 DW ratio= 2.142

'Khammuane Province

ELEIN_1.KHA=(1-IN.SAVE)*(14699.2+5.90993*(GDPIN.LAO)-4077.85*(PELE.LAO/DEF02.LAO)+ 300704.9*(DUM08))

't-value (.55) (3.12) (-.58) (36.69)

' OLS (2001-2010) R^2=.994 SD= 7,501.94 DW ratio= 1.065

'Savannakhet Province

ELEIN_1.SAV=(1-IN.SAVE)*(-19192.5+.461131*(ELEIN_1.SAV(1))+10.9129*(GDPIN.LAO)-734.484 *(PELE.LAO/DEF02.LAO)+322451.1*(DUM09))

't-value (-.51) (9.31) (2.40) (-.07) (23.52)

' OLS (2001-2010) R^2=.993 SD= 10,445.4 DW ratio= 2.233

'Saravane Province

ELEIN_1.SAR=(1-IN.SAVE)*(6390.00+.123482*(ELEIN_1.SAR(1))+.583364*(GDPIN.LAO)-1283.51 *(PELE.LAO/DEF02.LAO)+5956.18*(DUM07))

't-value (.93) (1.04) (1.80) (-.79) (7.47)

' OLS (2002-2010) R^2=.93 SD= 683.0675 DW ratio= 1.815

'Sekong Province

ELEIN_1.SEK=(1-IN.SAVE)*(-221.973+.677989*(ELEIN_1.SEK(1))+.257259*(GDPIN.LAO)-126.471 *(PELE.LAO/DEF02.LAO))

't-value (-.29) (2.19) (1.74) (-.59)

' OLS (2001-2010) R^2=.937 SD= 211.2031 DW ratio= 2.356

'Champassack Province

ELEIN_1.CHA=(1-IN.SAVE)*(2727.99+.778619*(ELEIN_1.CHA(1))+1.68414*(GDPIN.LAO)-1110.45 *(PELE.LAO/DEF02.LAO)+3378.80*(DUM02))

't-value (.24) (1.33) (.74) (-.32) (1.01)

' OLS (2001-2010) R^2=.858 SD= 2,434.46 DW ratio= 1.566

'Attapeu Province

ELEIN_1.ATT=(1-IN.SAVE)*(244.820+.511336*(ELEIN_1.ATT(1))+.463746*(GDPIN.LAO)-427.856* (PELE.LAO/DEF02.LAO))

't-value (.27) (2.16) (3.08) (-1.67)
' OLS (2001-2010) R^2=.951 SD= 256.9405 DW ratio= 2.29
'

' Industrial Sector (Except Large-Industry) by Region
ELEIN_1.NOR=ELEIN_1.PHO+ELEIN_1.LNA+ELEIN_1.OUD+ELEIN_1.BOK+ELEIN_1.LPR+ELEIN_1.XAY
ELEIN_1.CEN_1=ELEIN_1.CAP+ELEIN_1.VIE+ELEIN_1.HUA+ELEIN_1.XIE
ELEIN_1.CEN_2=ELEIN_1.BOR+ELEIN_1.KHA+ELEIN_1.SAV
ELEIN_1.SOU=ELEIN_1.SAR+ELEIN_1.SEK+ELEIN_1.CHA+ELEIN_1.ATT
'Whole Country Total
ELEIN_1.LAO=ELEIN_1.NOR+ELEIN_1.CEN_1+ELEIN_1.CEN_2+ELEIN_1.SOU
'

'Projected Industry Demand in Future is Given
' Projected Industry by Region
ELEIN_2.NOR=ELEIN_2.PHO+ELEIN_2.LNA+ELEIN_2.OUD+ELEIN_2.BOK+ELEIN_2.LPR+ELEIN_2.XAY
ELEIN_2.CEN_1=ELEIN_2.CAP+ELEIN_2.VIE+ELEIN_2.HUA+ELEIN_2.XIE
ELEIN_2.CEN_2=ELEIN_2.BOR+ELEIN_2.KHA+ELEIN_2.SAV
ELEIN_2.SOU=ELEIN_2.SAR+ELEIN_2.SEK+ELEIN_2.CHA+ELEIN_2.ATT
'Whole Country Total
ELEIN_2.LAO=ELEIN_2.NOR+ELEIN_2.CEN_1+ELEIN_2.CEN_2+ELEIN_2.SOU
'

'Industrial Sector Total
ELEIN.CAP=ELEIN_1.CAP+ELEIN_2.CAP
ELEIN.PHO=ELEIN_1.PHO+ELEIN_2.PHO
ELEIN.LNA=ELEIN_1.LNA+ELEIN_2.LNA
ELEIN.OUD=ELEIN_1.OUD+ELEIN_2.OUD
ELEIN.BOK=ELEIN_1.BOK+ELEIN_2.BOK
ELEIN.LPR=ELEIN_1.LPR+ELEIN_2.LPR
ELEIN.HUA=ELEIN_1.HUA+ELEIN_2.HUA
ELEIN.XAY=ELEIN_1.XAY+ELEIN_2.XAY
ELEIN.XIE=ELEIN_1.XIE+ELEIN_2.XIE
ELEIN.VIE=ELEIN_1.VIE+ELEIN_2.VIE
ELEIN.BOR=ELEIN_1.BOR+ELEIN_2.BOR
ELEIN.KHA=ELEIN_1.KHA+ELEIN_2.KHA
ELEIN.SAV=ELEIN_1.SAV+ELEIN_2.SAV
ELEIN.SAR=ELEIN_1.SAR+ELEIN_2.SAR
ELEIN.SEK=ELEIN_1.SEK+ELEIN_2.SEK
ELEIN.CHA=ELEIN_1.CHA+ELEIN_2.CHA
ELEIN.ATT=ELEIN_1.ATT+ELEIN_2.ATT

'

'Industrial Sector by Region

ELEIN.NOR=ELEIN.PHO+ELEIN.LNA+ELEIN.OUD+ELEIN.BOK+ELEIN.LPR+ELEIN.XAY

ELEIN.CEN_1=ELEIN.CAP+ELEIN.VIE+ELEIN.HUA+ELEIN.XIE

ELEIN.CEN_2=ELEIN.BOR+ELEIN.KHA+ELEIN.SAV

ELEIN.SOU=ELEIN.SAR+ELEIN.SEK+ELEIN.CHA+ELEIN.ATT

'Whole Country Total

ELEIN.LAO=ELEIN.NOR+ELEIN.CEN_1+ELEIN.CEN_2+ELEIN.SOU

'

'---------- LARGE INDUSTRY SECTOR ----------

'Large Industry Sector Demand in Future is Given

'Large Industry Sector by Region

ELELI.NOR=ELELI.PHO+ELELI.LNA+ELELI.OUD+ELELI.BOK+ELELI.LPR+ELELI.XAY

ELELI.CEN_1=ELELI.CAP+ELELI.VIE+ELELI.HUA+ELELI.XIE

ELELI.CEN_2=ELELI.BOR+ELELI.KHA+ELELI.SAV

ELELI.SOU=ELELI.SAR+ELELI.SEK+ELELI.CHA+ELELI.ATT

'Whole Country Total

ELELI.LAO=ELELI.NOR+ELELI.CEN_1+ELELI.CEN_2+ELELI.SOU

'

'---------- AGRICULTUAL SECTOR ----------

'Vientiane Cap.

ELEAG.CAP=(1-AG.SAVE)*(6579.21+.055803*(ELEAG.CAP(1))+1.61844*(GDPA.LAO))

' (.43) (.13) (.72)

' OLS (2003-2010) R^2=. SD= 3,674.37 DW ratio= 1.965

'Phongsaly Province

ELEAG.PHO=(1-AG.SAVE)*ELEAG.PHO(1)

'Luang Namtha Province

ELEAG.LNA=(1-AG.SAVE)*ELEAG.LNA(1)

'Oudomxai Province

ELEAG.OUD=(1-AG.SAVE)*(-7.31035+.476536*(ELEAG.OUD(1))+.000812*(GDPA.LAO))

' (-.92) (7.76) (.88)

' OLS (2003-2010) R^2=.933 SD= 1.34914 DW ratio= 2.8

'Bokeo Province

ELEAG.BOK=(1-AG.SAVE)*ELEAG.BOK(1)

'Luang Prabang Province

ELEAG.LPR=(1-AG.SAVE)*(-37.9601+.549006*(ELEAG.LPR(1))+.004558*(GDPA.LAO))

' (-.26) (3.27) (.26)

' OLS (2001-2010) R^2=.62 SD= 33.1084 DW ratio= 2.522

'Huaphanh Province

ELEAG.HUA=(1-AG.SAVE)*(4.73869+.606947*(ELEAG.HUA(1))+.003540*(GDPA.LAO))

'   (.01)   (1.26)   (.11)

' OLS   (2004-2010)   R^2=.5   SD= 23.1959   DW ratio= 1.683

'Xayabury Province

ELEAG.XAY=(1-AG.SAVE)*(-244.437+.128510*(ELEAG.XAY(1))+.038812*(GDPA.LAO)+107.801*(DUM03)+80.4361*(DUM09))

't-value   (-1.51) (.53) (1.79) (2.58) (1.90)

' OLS   (2001-2010)   R^2=.676   SD= 35.8612   DW ratio= 2.366

'Xiengkhuang Province

ELEAG.XIE=(1-AG.SAVE)*ELEAG.XIE(1)

'Vientiane Province

ELEAG.VIE=(1-AG.SAVE)*(1150.51+.209027*(GDPA.LAO)+1525.95*(DUM07))

'   (1.27)   (1.84)   (5.10)

' OLS   (2001-2010)   R^2=.783   SD= 278.0468   DW ratio= 2.189

'Borikhamxay Province

ELEAG.BOR=(1-AG.SAVE)*(480.410+.766752*(ELEAG.BOR(1)))

'   (.63)   (2.38)

' OLS   (2001-2010)   R^2=.341   SD= 368.5697   DW ratio= 1.43

'Khammuane Province

ELEAG.KHA=(1-AG.SAVE)*(4575.48+.339968*(ELEAG.KHA(1))-214.709*(PELE.LAO/DEF02.LAO))

'   (1.43)   (.66)   (-.22)

' OLS   (2001-2010)   R^2=.   SD= 935.1218   DW ratio= 1.888

'Savannakhet Province

ELEAG.SAV=(1-AG.SAVE)*(-6488.52+.083890*(ELEAG.SAV(1))+1.17987*(GDPA.LAO)+2098.84*(DUM08))

'   (-2.80)   (.42)   (3.49)   (3.16)

' OLS   (2001-2010)   R^2=.848   SD= 591.7885   DW ratio= 1.753

'Saravane Province

ELEAG.SAR=(1-AG.SAVE)*(589.656+.141570*(GDPA.LAO))

'   (.65)   (1.26)

' OLS   (2001-2010)   R^2=.061   SD= 281.7962   DW ratio= 3.054

'Sekong Province

ELEAG.SEK=(1-AG.SAVE)*(-15.9903+.000641*(ELEAG.SEK(1))+.002017*(GDPA.LAO))

'   (-1.39)   (.00)   (1.46)

' OLS   (2006-2010)   R^2=.45   SD= 1.02179   DW ratio= 2.924

'Champassack Province

ELEAG.CHA=(1-AG.SAVE)*(-1069.80+.064523*(ELEAG.CHA(1))+.373201*(GDPA.LAO)+776.909*(DUM08))

'   (-.53)   (.16)   (1.49)   (1.24)

' OLS   (2002-2010)   R^2=.263   SD= 526.9846   DW ratio= 1.849

'Attapeu Province

ELEAG.ATT=(1-AG.SAVE)*(-2197.32+.122485*(ELEAG.ATT(1))+.300091*(GDPA.LAO))

' (-3.51) (.41) (3.62)

' OLS (2001-2010) R^2=.882 SD= 99.4351 DW ratio= 1.765

'

'Agricultural Sector by Region

ELEAG.NOR=ELEAG.PHO+ELEAG.LNA+ELEAG.OUD+ELEAG.BOK+ELEAG.LPR+ELEAG.XAY

ELEAG.CEN_1=ELEAG.CAP+ELEAG.VIE+ELEAG.HUA+ELEAG.XIE

ELEAG.CEN_2=ELEAG.BOR+ELEAG.KHA+ELEAG.SAV

ELEAG.SOU=ELEAG.SAR+ELEAG.SEK+ELEAG.CHA+ELEAG.ATT

'Whole Country Total

ELEAG.LAO=ELEAG.NOR+ELEAG.CEN_1+ELEAG.CEN_2+ELEAG.SOU

'

'---------- TOTAL (By Province & Region) ----------

'Electricity Demand by Province

ELE.CAP=ELERE.CAP+ELECM.CAP+ELEIN.CAP+ELELI.CAP+ELEAG.CAP

ELE.PHO=ELERE.PHO+ELECM.PHO+ELEIN.PHO+ELELI.PHO+ELEAG.PHO

ELE.LNA=ELERE.LNA+ELECM.LNA+ELEIN.LNA+ELELI.LNA+ELEAG.LNA

ELE.OUD=ELERE.OUD+ELECM.OUD+ELEIN.OUD+ELELI.OUD+ELEAG.OUD

ELE.BOK=ELERE.BOK+ELECM.BOK+ELEIN.BOK+ELELI.BOK+ELEAG.BOK

ELE.LPR=ELERE.LPR+ELECM.LPR+ELEIN.LPR+ELELI.LPR+ELEAG.LPR

ELE.HUA=ELERE.HUA+ELECM.HUA+ELEIN.HUA+ELELI.HUA+ELEAG.HUA

ELE.XAY=ELERE.XAY+ELECM.XAY+ELEIN.XAY+ELELI.XAY+ELEAG.XAY

ELE.XIE=ELERE.XIE+ELECM.XIE+ELEIN.XIE+ELELI.XIE+ELEAG.XIE

ELE.VIE=ELERE.VIE+ELECM.VIE+ELEIN.VIE+ELELI.VIE+ELEAG.VIE

ELE.BOR=ELERE.BOR+ELECM.BOR+ELEIN.BOR+ELELI.BOR+ELEAG.BOR

ELE.KHA=ELERE.KHA+ELECM.KHA+ELEIN.KHA+ELELI.KHA+ELEAG.KHA

ELE.SAV=ELERE.SAV+ELECM.SAV+ELEIN.SAV+ELELI.SAV+ELEAG.SAV

ELE.SAR=ELERE.SAR+ELECM.SAR+ELEIN.SAR+ELELI.SAR+ELEAG.SAR

ELE.SEK=ELERE.SEK+ELECM.SEK+ELEIN.SEK+ELELI.SEK+ELEAG.SEK

ELE.CHA=ELERE.CHA+ELECM.CHA+ELEIN.CHA+ELELI.CHA+ELEAG.CHA

ELE.ATT=ELERE.ATT+ELECM.ATT+ELEIN.ATT+ELELI.ATT+ELEAG.ATT

'Electricity Demand by Region

ELE.NOR=ELE.PHO+ELE.LNA+ELE.OUD+ELE.BOK+ELE.LPR+ELE.XAY

ELE.CEN_1=ELE.CAP+ELE.VIE+ELE.HUA+ELE.XIE

ELE.CEN_2=ELE.BOR+ELE.KHA+ELE.SAV

ELE.SOU=ELE.SAR+ELE.SEK+ELE.CHA+ELE.ATT

'Whole Country Total

ELE.LAO=ELE.NOR+ELE.CEN_1+ELE.CEN_2+ELE.SOU

'

'---------------End

Note: OLS = Ordinary Least Square Method
R^2 (R-square) = Coefficient of Determination
SD = Standard Deviation
DW = David Watson Coefficient
(***) = t –Value of each parameter of an equation

Regarding the above Statistical terms, please look into a suitable textbook on Econometrics. As a reference book, "Introductory: Econometrics – A modern approach (5th Edition)", Jeffrey M. Wooldridge, 2009, is read by most of the model-builders in the world who would like to study the basic knowledge for Econometrics from a viewpoint of Statistics, Mathematics, and Economics in more in details.

2.2.8 Preconditions

Preconditions towards 2022 are shown by the following contents

(1) Macro Economic Data

Table 2-5 : Macro Economic Data

(Unit:10^9 kips, or 2002=100)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Real GDP	34635.9	38099.5	41909.5	46100.4	50710.5	54260.2	58058.4	62122.5	66471.1	71124.0	76102.7	81429.9
Real GDP by Commercial Sector	15696.9	17435.2	19319.8	21240.0	23296.4	25033.1	26717.6	28529.0	30367.0	32223.1	34082.0	36486.1
Real GDP by Indutrial Sector	6629.2	7557.2	8630.1	9887.9	11364.5	12593.5	13997.2	15613.3	17458.5	19560.0	21951.9	24021.4
Real GDP by Agricultural Sector	10102.6	10694.7	11321.6	12086.8	12891.3	13265.0	13750.0	14146.1	14554.2	14974.5	15408.4	15947.4
Private Consumption	24112.1	25952.0	28038.6	30361.0	32927.7	35372.9	37634.8	39994.1	42492.0	45153.2	47995.7	51034.9
Real GDP deflator	190.0	203.9	215.7	228.6	243.4	251.8	256.3	269.8	281.3	294.7	308.3	322.7

(source: MIP, ADB)

(2) Electrification Rate

Table 2.6 Electrification Rate

(Unit: %)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	100	100	100	100	100	100	100	100	100	100	100	100
PHO	24	29	35	40	45	52	59	66	72	78	80	81
LNA	52	53	53	54	55	57	59	61	62	64	66	68
OUD	40	44	48	52	55	60	64	68	72	76	78	80
BOK	64	65	66	67	68	70	73	75	77	78	81	84
LPR	63	64	65	66	67	69	71	73	75	77	79	81
HUA	47	52	56	61	65	69	74	78	81	85	87	89
XAY	79	82	84	86	89	91	93	95	97	99	98	98
XIE	55	58	62	65	68	73	77	81	85	89	90	91
VIE	85	86	87	88	89	90	92	93	94	95	96	97
BOR	83	84	85	86	86	88	90	92	93	95	96	97
KHA	83	84	85	86	87	88	89	91	92	93	94	95
SAV	77	78	79	80	81	84	87	89	92	94	95	96
SAR	69	70	72	73	73	76	78	81	83	85	87	89
SEK	53	56	59	62	65	70	75	80	84	88	90	91
CHA	81	83	84	86	87	89	90	92	93	94	95	96
ATT	48	52	56	60	63	66	69	72	75	78	80	83

(source: EDL, MEM)

(3)-1 Electricity Demand by Large Industry sector with less than 50 MW.

Table 2-6 : Electricity Demand by Large Industry sector with less than 50 MW.

(Unit: MWh)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	0.0	21900.0	65688.0	152464.0	263952.0	305757.2	405944.4	421099.2	476492.4	557161.6	560052.4	604817.6
PHO	0.0	0.0	0.0	0.0	31536.0	73584.0	99864.0	141912.0	159256.8	187113.6	190792.8	194472.0
LNA	0.0	0.0	0.0	15768.0	31536.0	63072.0	78840.0	105120.0	107222.4	109324.8	111427.2	113529.6
OUD	0.0	0.0	17520.0	46428.0	117384.0	177127.2	194296.8	223555.2	252813.6	257368.8	262887.6	267968.4
BOK	0.0	0.0	12300.0	30700.0	43000.0	61400.0	92100.0	122800.0	125300.0	127800.0	130300.0	132900.0
LPR	0.0	13140.0	35040.0	59568.0	99864.0	124392.0	126757.2	129648.0	132013.2	134904.0	137269.2	140160.0
HUA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XAY	0.0	0.0	0.0	0.0	0.0	15768.0	47304.0	63072.0	78840.0	105120.0	157680.0	210240.0
XIE	0.0	0.0	0.0	35040.0	135780.0	232140.0	306600.0	365730.0	438000.0	443256.0	448950.0	454206.0
VIE	0.0	252288.0	320616.0	414523.2	501422.4	740745.6	771405.6	816432.0	841485.6	844551.6	848581.2	851647.2
BOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KHA	0.0	39420.0	39420.0	39420.0	223380.0	335508.0	430992.0	459900.0	491874.0	499232.4	507028.8	514825.2
SAV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SAR	0.0	21900.0	39420.0	52560.0	65700.0	87600.0	109500.0	111690.0	113880.0	116070.0	118698.0	120888.0
SEK	0.0	0.0	0.0	28300.0	50900.0	67900.0	84900.0	198100.0	249000.0	254000.0	259100.0	264300.0
CHA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ATT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(source: EDL, MEM)

(3)-2 Lists of Large Industries with less than 50 MW

Table 2-7 : Lists of Large Industries with less than 50 MW

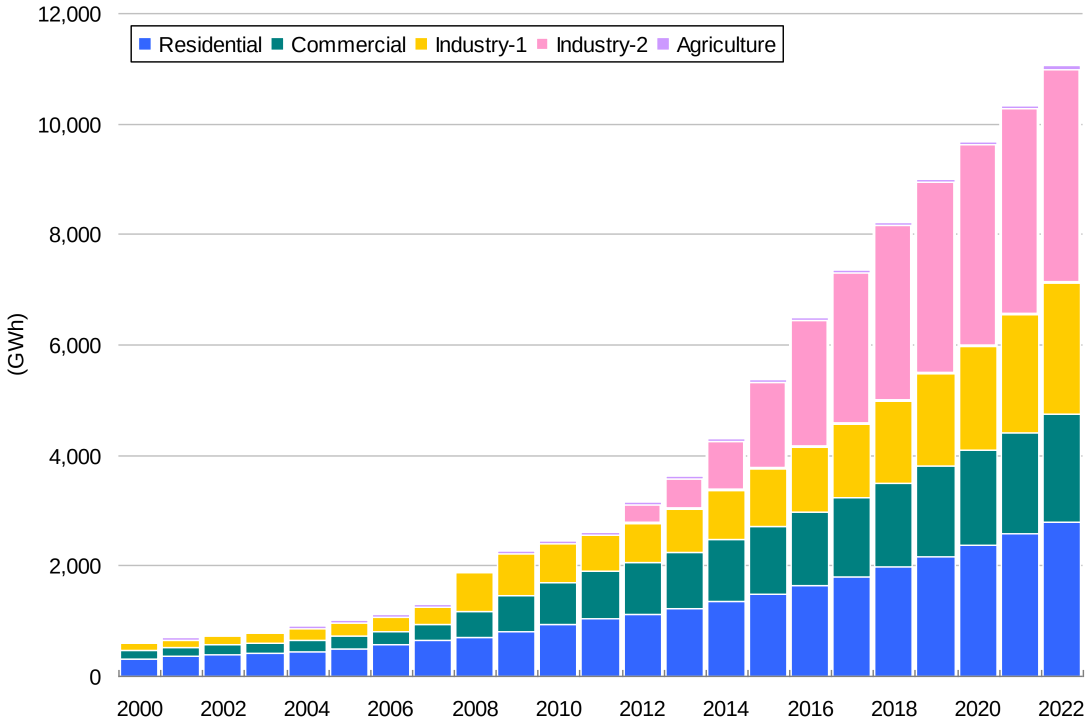
Province	Description
Vientiane Capital	Gold Mining at Khok Pheung Village, Sangthong District
Vientiane Capital	Kea Potash Factory at Thongmang Village, Saythany District
Vientiane Capital	Kea Potash Factory at Nathom Village, Saythany District
Vientiane Capital	Japan industries special zone Koksaad, Xaythany District
Vientiane Capital	EZC Vientiane Nelamit at DongPhoXee Village, Hatxaifong District
Phongsaly	Copper Mining 1 at Yot Ou District
Phongsaly	Copper Mining 2 at Yot Ou District
Luangnamtha	Copper Mining at Houay Mo, Long District
Oudomxai	Copper Mining at Kiew Chep Village-, Namo District
Oudomxai	Iron melting factory, at Phu Phan Village, La District
Oudomxai	Lead- Zinc Factory at Nam Pheng Village, Namo District
Oudomxai	Cement Factory at Thong Na Village, Namo District
Bokeo	Dokngiewkham
Luangprabang	Gold Mining at Phapon Village, Pak Ou District
Luangprabang	Cement factory at Many Village, Nambak District
S(x)ayaboury	Copper Mining at Pang Kham Village, Paklay District
Xiengkhuang	Iron melting factory, at Nator Village, Khoun District
Xiengkhuang	Iron melting factory, at Yot Pieng Village, Pek District
Xiengkhuang	Iron melting factory, at Namchan Village, Saysomboon District
Xiengkhuang	Silicon factory, at Xai village, Pukuad District
Vientiane Province	Houaysai Gold/copper Mining
Vientiane Province	Phubia Gold/copper Mining
Vientiane Province	Gold/Copper Mining at Maipakphoun Village, Sanakham District
Vientiane Province	Iron melting factory, at Vangvieng District
Vientiane Province	Iron melting factory, at Namchan Village, Saysomboon District
Vientiane Province	Cement Factory at Vangvieng (Extension)
Khammouane	Jiaxi Mining at Thakhek District
Khammouane	Metal Melting Factory at Nong Cheun-Borneng Village, Hinboon District
Khammouane	Cement Factory at Nakham Village, Thakhek District (Existing)
Khammouane	Cement Factory at Nakham Village, Thakhek District (Extension)
Saravan	Cement Factory at Ta Leo Village, Saravane District
Sekong	Aluminum at Daklan Village, Dakjung District
Champasak	Aluminium at Paksong District(SLACO)for the entire mine
Champasak	Aluminum at Paksong District(SINOMA) for the entire mine
Champasak	Aluminum at Paksong District(SINOMA) for Alumina refinery
Attapeu	Aluminum at Paksong District(SLACO) for Alumina refinery

(source: EDL, MEM)

2.2.9 Details of output data

Figures and Tables on detailed output data are shown by the following contents.

(1) Electricity Demand of the whole Laos by Sector



(Source : Study Team)

Figure 2-8 : Electricity Demand of the whole Laos by Sector

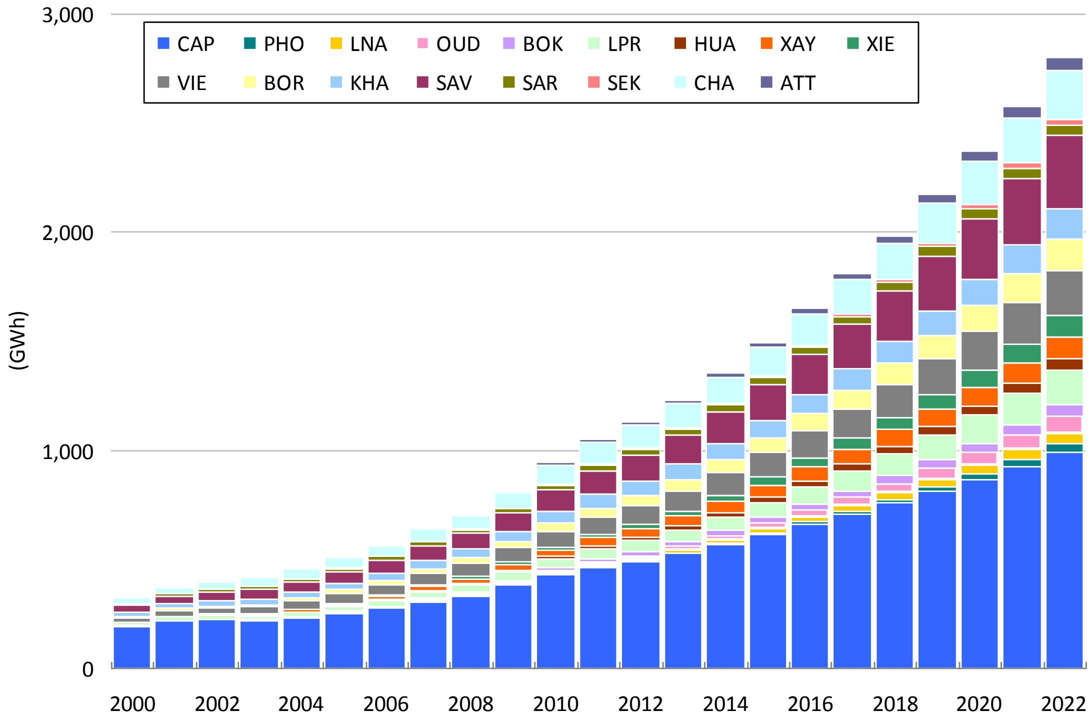
Table 2-8 : Electricity Demand of the whole Laos by Sector

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	322	371	394	413	453	507	565	642	707	813	943	1,047	1,128	1,231	1,354	1,494	1,653	1,812	1,985	2,171	2,369	2,576	2,799
Commercial	147	160	173	178	189	229	250	300	461	645	749	845	927	1,021	1,120	1,227	1,327	1,423	1,523	1,625	1,730	1,835	1,956
Industry-1	135	130	164	189	219	237	258	309	703	760	707	668	702	783	896	1,037	1,175	1,322	1,487	1,673	1,884	2,124	2,358
Industry-2	0	0	0	0	0	0	0	0	0	0	0	0	349	530	875	1,564	2,285	2,749	3,159	3,466	3,636	3,733	3,870
Agriculture	33	40	35	33	39	35	40	47	44	39	43	47	49	52	56	59	61	63	64	66	68	70	72
Total	637	702	766	813	900	1,008	1,112	1,298	1,916	2,258	2,441	2,607	4,241	5,020	6,517	8,075	10,072	12,608	13,934	15,001	19,496	19,491	20,270

(Source : Study Team)

(2) Electricity Demand of Residential Sector by Region



(Source : Study Team)

Figure 2-9 : Electricity Demand of Residential Sector by Region

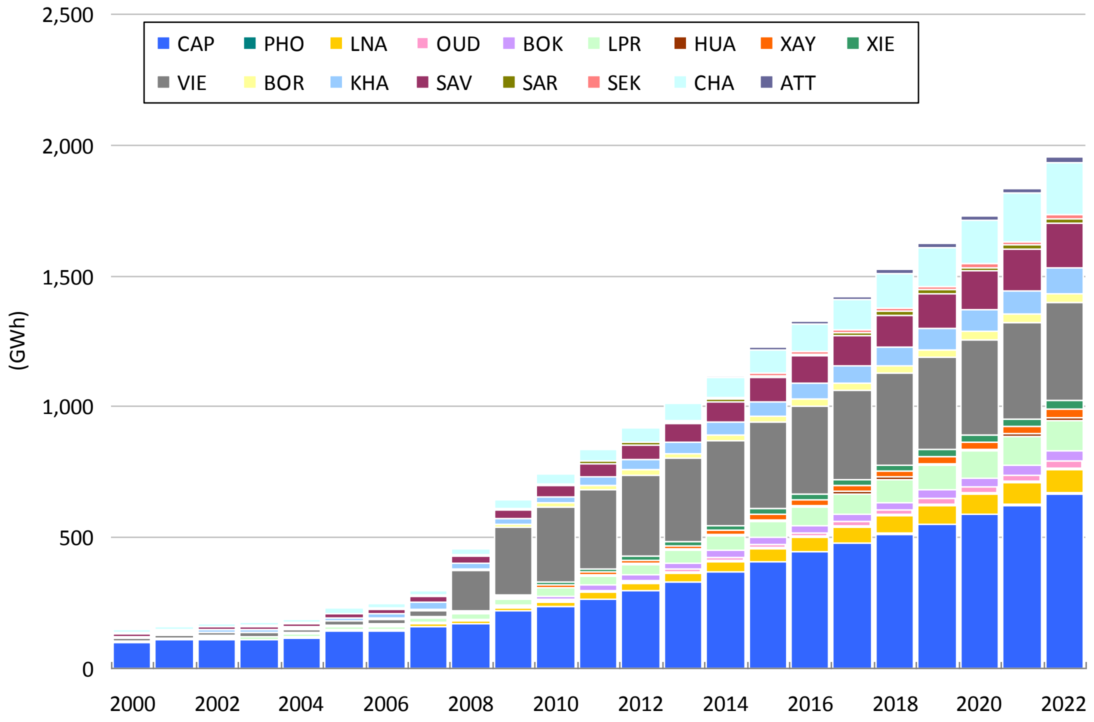
Table 2-9 : Electricity Demand of Residential Sector by Region

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	193	218	222	217	233	252	275	307	330	380	429	465	492	527	569	616	664	709	759	811	865	927	993
PHO	0	0	0	0	0	0	0	1	1	1	1	2	3	4	6	8	10	14	17	22	27	31	35
LNA	0	0	0	0	0	0	1	3	4	6	7	7	9	11	13	16	20	23	28	32	38	44	51
OUD	0	0	2	3	0	4	4	5	5	7	10	12	15	18	22	27	32	38	44	51	59	67	75
BOK	2	3	3	4	4	6	7	9	10	12	14	15	17	19	22	24	28	31	35	39	43	49	55
LPR	13	16	15	17	18	21	24	26	33	37	43	46	51	57	64	72	82	92	103	115	128	142	158
HUA	1	4	4	4	4	5	5	6	7	7	8	12	14	17	19	23	26	30	33	37	42	46	51
XAY	0	0	4	6	9	12	15	18	21	24	29	39	41	45	50	56	63	68	75	81	89	95	101
XIE	0	0	0	1	4	0	6	7	8	11	13	14	18	22	27	33	41	49	58	68	79	89	99
VIE	23	26	28	31	38	44	49	54	60	66	75	79	87	95	104	115	126	138	150	162	176	189	204
BOR	5	8	9	11	14	17	20	23	26	30	36	42	47	53	59	67	76	86	97	108	121	133	148
KHA	19	21	23	26	25	30	34	38	40	46	53	63	66	70	76	82	89	96	103	111	119	128	137
SAV	31	36	41	45	48	53	60	68	73	84	98	111	120	131	144	160	181	203	227	252	280	307	336
SAR	7	9	9	11	13	14	14	14	16	18	23	26	27	29	31	32	35	37	39	42	44	47	50
SEK	0	0	0	0	0	1	1	3	4	4	6	5	5	6	7	9	11	13	15	18	21	24	27
CHA	27	31	34	37	43	47	50	56	63	72	88	98	105	113	122	133	144	156	168	180	194	207	222
ATT	0	0	0	0	0	0	2	5	5	6	8	11	12	15	18	21	25	29	34	39	45	51	58
Total	322	371	394	413	453	507	565	642	707	813	943	1,047	1,128	1,231	1,354	1,494	1,653	1,812	1,985	2,171	2,369	2,576	2,799

(Source : Study Team)

(3) Electricity Demand of Commercial Sector by Region



(Source : Study Team)

Figure 2-10 : Electricity Demand of Commercial Sector by Region

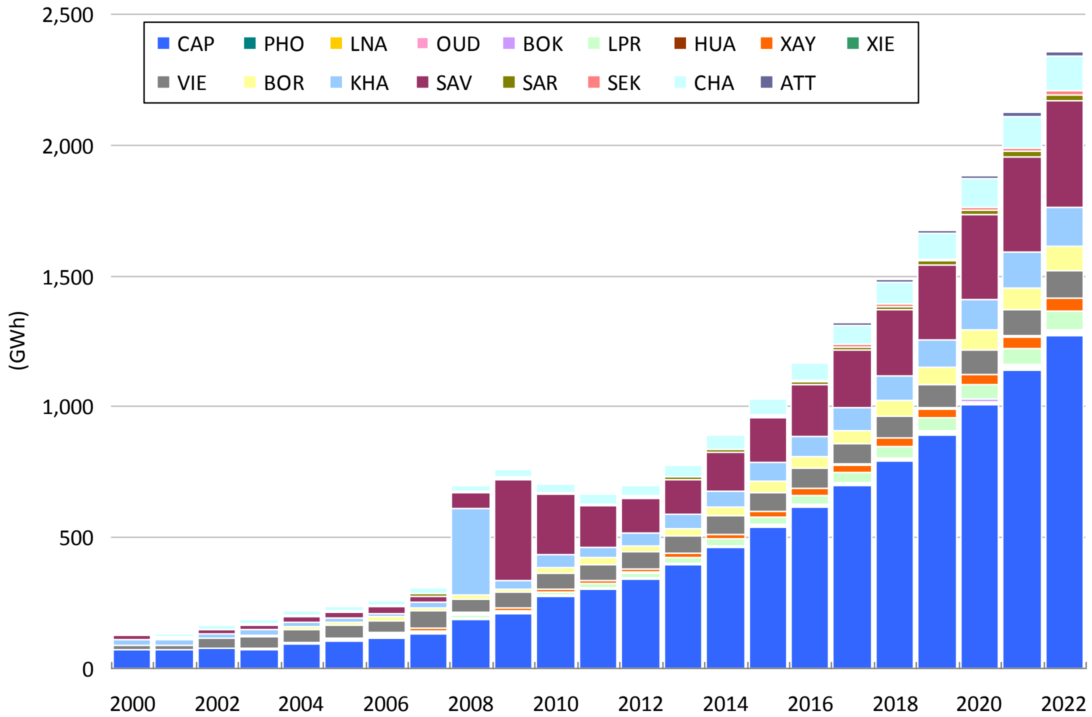
Table 2-10 : Electricity Demand of Commercial Sector by Region

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	97	108	113	108	118	144	142	158	170	219	236	265	295	330	368	407	444	478	514	550	586	623	667
PHO	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	3	3	3	3	4
LNA	0	0	0	0	0	0	1	10	12	13	19	25	29	35	41	48	54	60	65	72	78	84	91
OUD	0	0	1	1	1	2	2	3	3	4	6	8	10	12	14	16	18	20	23	25	27	30	32
BOK	1	1	1	1	1	2	3	3	4	8	15	20	22	24	26	28	29	30	31	33	34	35	37
LPR	7	8	9	10	10	12	14	16	20	23	28	35	41	48	55	63	70	77	85	93	100	108	117
HUA	1	1	1	1	1	1	2	2	2	3	3	4	4	5	6	7	7	8	9	10	10	11	12
XAY	0	0	1	1	2	2	3	4	5	6	8	11	12	14	16	18	20	22	24	26	28	30	32
XIE	0	0	0	0	1	2	2	3	4	6	13	15	16	17	19	21	22	23	25	26	27	29	31
VIE	8	10	11	15	13	14	19	24	156	260	287	301	309	316	323	330	337	343	349	355	362	369	377
BOR	2	2	2	3	3	4	4	5	6	7	14	16	18	20	21	23	24	25	27	28	29	31	33
KHA	7	8	7	8	7	10	17	26	23	21	26	34	38	44	50	57	62	67	73	79	84	90	97
SAV	11	7	13	14	14	15	18	20	22	33	41	50	59	69	80	91	103	114	125	136	148	159	172
SAR	2	2	2	3	3	3	3	3	7	6	7	7	7	8	8	9	10	11	12	13	14	15	16
SEK	0	0	0	0	0	0	1	1	2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CHA	11	12	13	14	14	17	18	19	22	30	36	44	53	64	75	88	102	117	132	148	165	183	202
ATT	0	0	0	0	0	0	1	3	3	3	5	6	7	9	10	12	13	15	16	18	19	21	22
Total	147	160	173	178	189	229	250	300	461	645	749	845	927	1,021	1,120	1,227	1,327	1,423	1,523	1,625	1,730	1,835	1,956

(Source : Study Team)

(4) Electricity Demand of Industrial Sector (excluding Large Industry) by Region



(Source : Study Team)

Figure 2-11 : Electricity Demand of Industrial Sector (excluding Large Industry) by Region

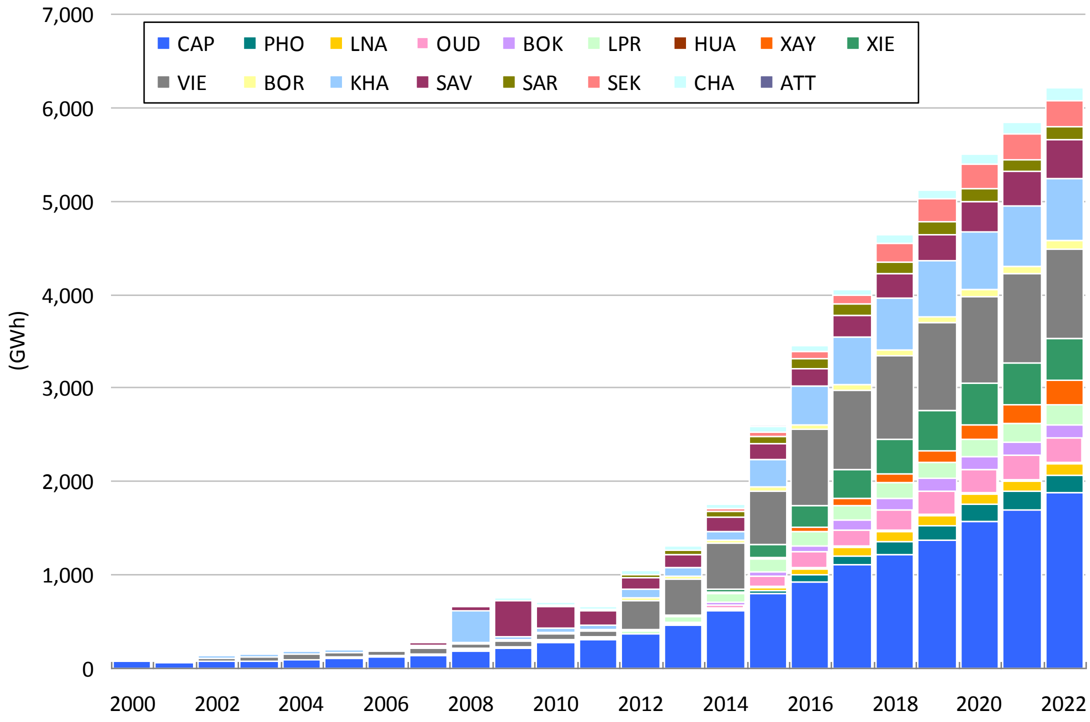
Table 2-11 : Electricity Demand of Industrial Sector (excluding Large Industry) by Region

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	71	69	76	73	93	105	117	135	189	209	275	304	344	396	462	540	617	699	790	893	1,009	1,140	1,270
PHO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
LNA	0	0	0	0	0	0	1	0	0	1	1	1	1	2	2	2	3	3	4	5	6	6	7
OUD	0	0	0	0	0	1	1	1	1	1	2	2	2	2	3	3	4	4	4	5	6	6	7
BOK	0	0	0	0	0	0	1	1	1	2	2	2	2	3	3	4	4	5	6	7	7	9	9
LPR	1	1	1	1	1	3	7	9	10	10	12	14	17	20	24	28	33	37	42	48	54	62	69
HUA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
XAY	0	0	1	1	2	4	6	7	7	9	11	12	13	15	18	21	24	27	31	34	39	44	49
XIE	0	0	0	0	2	3	3	3	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3
VIE	15	17	34	46	50	50	47	63	53	56	58	60	61	64	67	71	74	78	82	86	91	97	103
BOR	1	2	2	5	9	10	13	13	15	14	22	23	26	30	36	42	47	53	60	68	76	86	95
KHA	23	20	17	22	21	17	15	19	331	31	50	42	46	53	61	70	77	86	96	107	119	134	146
SAV	13	9	16	17	19	23	25	26	59	389	229	157	133	134	148	171	195	221	251	285	324	368	411
SAR	2	2	3	4	4	4	6	11	6	6	7	7	7	8	9	10	11	12	13	15	16	18	19
SEK	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	6	7	8	10	11	13	14
CHA	9	10	14	18	17	16	16	18	24	27	31	35	39	44	50	58	66	74	84	94	106	119	133
ATT	0	0	0	0	0	0	1	2	2	2	3	4	4	5	6	7	9	10	11	13	15	17	19
Total	135	130	164	189	219	237	258	309	703	760	707	668	702	783	896	1,037	1,175	1,322	1,487	1,673	1,884	2,124	2,358

(Source : Study Team)

(5) Electricity Demand of Industrial Sector (including Large Industry with less than 50 MW) by Region



(Source : Study Team)

Figure 2-12 : Electricity Demand of Industrial Sector (including Large Industry with less than 50 MW) by Region

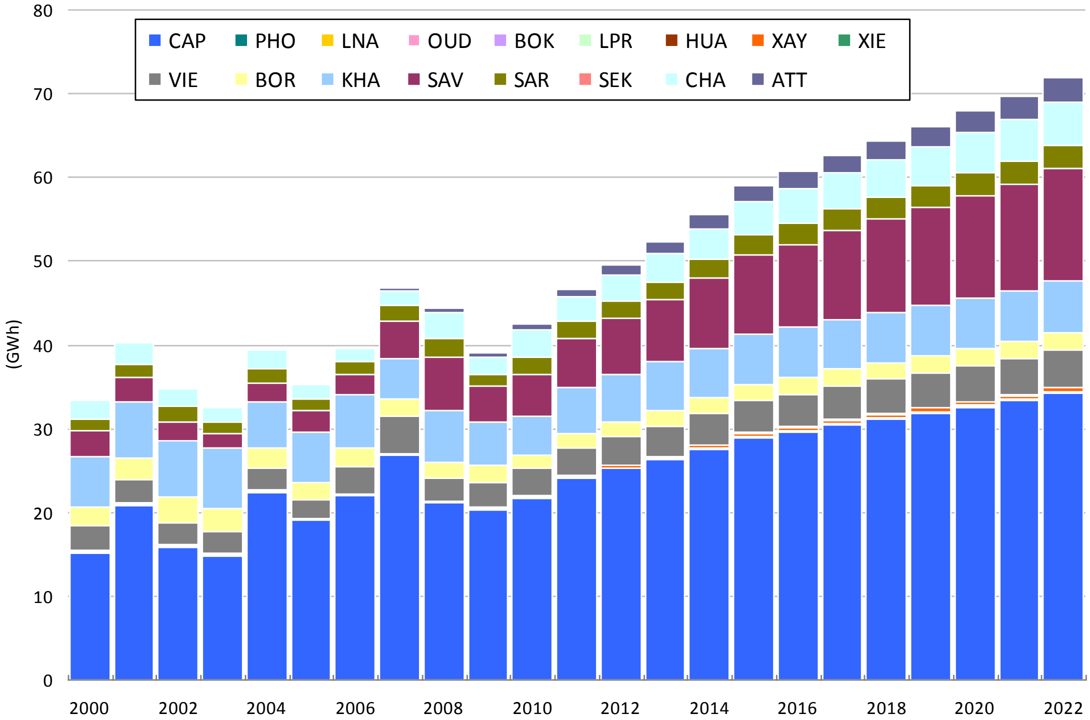
Table 2-12 : Electricity Demand of Industrial Sector (including Large Industry with less than 50 MW) by Region

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	71	69	76	73	93	105	117	135	189	209	275	304	366	462	614	804	923	1,105	1,212	1,369	1,566	1,700	1,875
PHO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	74	101	143	160	188	192	196
LNA	0	0	0	0	0	0	1	0	0	1	1	1	1	2	18	34	66	82	109	112	115	118	121
OUD	0	0	0	0	0	1	1	1	1	1	2	2	2	20	49	121	181	198	228	258	263	269	275
BOK	0	0	0	0	0	0	1	1	1	2	2	2	2	15	34	47	66	97	129	132	135	139	142
LPR	1	1	1	1	1	3	7	9	10	10	12	14	30	55	83	128	157	164	172	180	189	199	209
HUA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
XAY	0	0	1	1	2	4	6	7	7	9	11	12	13	15	18	21	40	74	94	113	144	202	259
XIE	0	0	0	0	2	3	3	3	2	2	2	2	2	3	38	138	235	309	369	441	446	452	457
VIE	15	17	34	46	50	50	47	63	53	56	58	60	314	384	482	572	815	849	898	928	936	946	954
BOR	1	2	2	5	9	10	13	13	15	14	22	23	26	30	36	42	47	53	60	68	76	86	95
KHA	23	20	17	22	21	17	15	19	331	31	50	42	85	92	100	293	413	517	555	599	619	641	661
SAV	13	9	16	17	19	23	25	26	59	389	229	157	133	134	148	171	195	221	251	285	324	368	411
SAR	2	2	3	4	4	4	6	11	6	6	7	7	29	48	62	76	99	122	125	129	132	137	140
SEK	0	0	0	0	0	0	0	1	1	2	2	3	3	4	33	56	74	92	206	259	265	272	278
CHA	9	10	14	18	17	16	16	18	24	27	31	35	39	44	50	58	66	74	84	94	106	119	133
ATT	0	0	0	0	0	0	1	2	2	2	3	4	4	5	6	7	9	10	11	13	15	17	19
Total	135	130	164	189	219	237	258	309	703	760	707	668	1,051	1,313	1,771	2,601	3,460	4,070	4,646	5,139	5,520	5,856	6,228

(Source : Study Team)

(6) Electricity Demand of Agricultural Sector by Region



(Source : Study Team)

Figure 2-13 : Electricity Demand of Agricultural Sector by Region

Table 2-13 : Electricity Demand of Agricultural Sector by Region

(Unit:GWh)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CAP	15	21	16	15	22	19	22	27	21	20	22	24	25	26	28	29	30	30	31	32	33	33	34
PHO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OUD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BOK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LPR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HUA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XAY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XIE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VIE	3	3	3	3	3	2	3	4	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
BOR	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
KHA	6	7	7	7	6	6	6	5	6	5	5	5	6	6	6	6	6	6	6	6	6	6	6
SAV	3	3	2	2	2	2	2	4	6	4	5	6	7	7	8	9	10	11	11	12	12	13	13
SAR	1	2	2	1	2	2	2	2	2	1	2	2	2	2	2	2	2	3	3	3	3	3	3
SEK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHA	2	3	2	2	2	2	2	2	3	2	3	3	3	3	4	4	4	4	4	5	5	5	5
ATT	0	0	0	0	0	0	0	0	1	0	1	1	1	1	2	2	2	2	2	2	3	3	3
Total	33	40	35	33	39	35	40	47	44	39	43	47	49	52	56	59	61	63	64	66	68	70	72

(Source : Study Team)

Chapter 3 Power system analysis

The most of the power source in Laos is hydropower and the amount of power supply largely fluctuates depending on the season. In addition, it does power trades with neighboring countries since it is landlocked country. For this reason, as a precondition to formulate power system planning, it is essential for EDL to formulate reasonable demand and supply planning considering demand-supply balance in detail. Therefore, in this study, the Study Team has proposed a calculation method which is on monthly basis instead of the conventional method which was on annual basis. The detail is explained in this chapter.

In addition, main elements when formulating power system planning by using power system analysis, such as voltage analysis, N-1 accident analysis, and short-circuit analysis are described.

3.1 Monthly demand and supply calculation

The demand and supply balance has been checked in the current PDP based on annual total electric energy. However, considering the balance between demand and supply, it is necessary to take into account of various situations such as bottlenecks in the dry season or rainy season. Therefore, monthly-based system planning is recommended in order to optimize power system development and power system operation.

Monthly demand and supply calculation enhances the accuracy of the system planning and can be a basis of power system operation. In concrete terms, monthly demand and supply calculation is used as follows,

- Confirm the Cost balance and energy security on a monthly basis.
- Review the priority and the commencement of operation of the planned power plants.
- Find out the optimal annual operation schedule for hydropower plants. (reservoir and pondage type plants etc.)
- Form the monthly system diagram and confirm the power flow in the rainy and dry season.
- Optimize the schedule of works of expansion and inspection which requires power outage.

The monthly electric energy is calculated based on the annual electric energy at receiving end in each province which is computed by applying econometric model as described in Chapter 1. The annual energy is allocated to each month according to the ratio calculated from the track records. It is the data at the receiving end and does not include the distribution or transmission loss. The monthly energy, which is referred to as generation requirement, is calculated by adding these losses to the monthly energy at the receiving end.

The procedure of monthly demand and supply calculation is described as below.

3.1.1 Data collection

Step1: Calculate the annual electric energy at receiving end for each province in the future by the using econometric model

Step2: Collect the actual value of the monthly electric energy demand (the electric energy sold) for each province

Step3: Collect the actual data of the monthly electric energy demand at receiving end and monthly electric energy at sending end of substation. Thus, distribution loss is calculated based on this data.

Step4: Collect the actual data of the monthly maximum demand at sending end of substation and monthly total electric energy at sending end of substation. Thus, power factor is calculated based on the data.

3.1.2 Monthly demand calculation

Step1: Allocate the future annual electric energy at receiving end, which is calculated by using the econometric model, to each province in each month.

Step2: Calculate the electric energy per month at sending end of substation (excluding transmission loss) by adding the distribution loss to the electric energy per month at receiving end.

Step3: Calculate the peak load at sending end of substation (excluding transmission loss) per month for each province based on monthly electric energy at sending end of substation and monthly load factor

Step4: Distribute the sending end of substation peak load per month in each province to each substation as the peak load per month, which is excluding transmission loss.

Step5: Figure out the monthly transmission loss by performing PSS/E analysis based on monthly peak load and generation plan at each substation

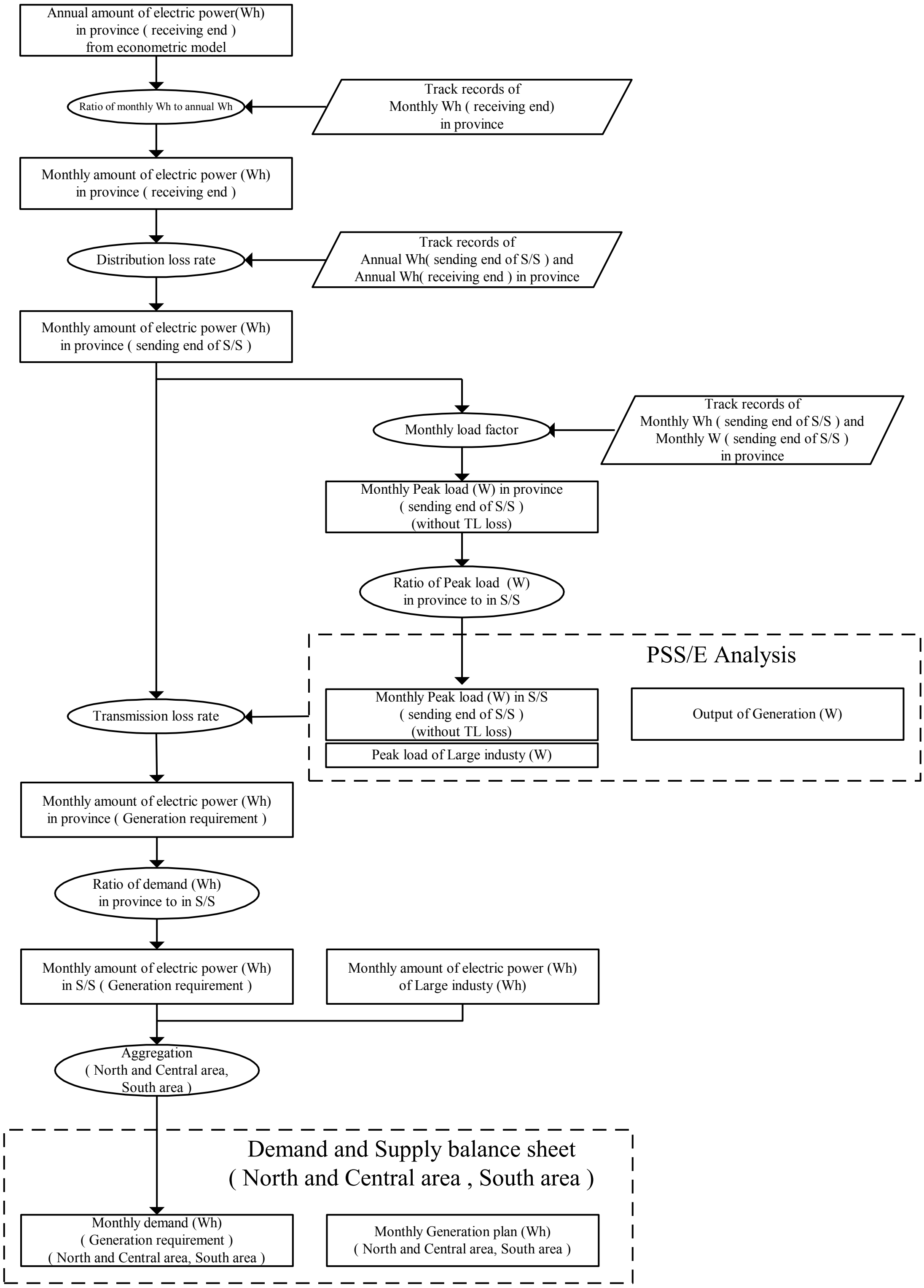
Step6: Figure out the electric energy per month at sending end of substation (including transmission loss) by adding the transmission loss to the electric energy per month at sending end of substation (excluding transmission loss)

Step7: Allocate the electric energy per month in each province (including transmission loss) to each substation as the electric energy per month (including transmission loss)

Step8: Output it as a monthly balance sheet by summing up the electric energy per month (including transmission loss) at each substation in North-middle and South

3.1.3 The flow of balance sheet formation

The flowchart below shows the procedure of making monthly demand and supply balance sheet.



(Source : Study Team)

Figure 3-1 : Flow of the monthly demand and supply calculation

3.1.4 Input data prerequisites

The prerequisites of input data for monthly demand and supply balance sheet are as below.

1) The ratio of monthly to annual

The ratio of monthly electric energy (Wh) to annual electric energy (Wh) is calculated using the average of the track records in the past 5 years.

2) Distribution loss rate

The distribution loss rate are calculated based on the track records of Wh (sending end) and Wh (receiving end). The target of distribution loss in 2030 is 6%, and defining it as the starting point, the coefficient (distribution loss increase/year) between 2012 and 2020 is calculated by a linear interpolation.

3) Transmission loss rate

Transmission loss rate is calculated using the software PSS/E. These are used for the calculation of the demand (Wh and W) as generation requirements.

4) Monthly load factor

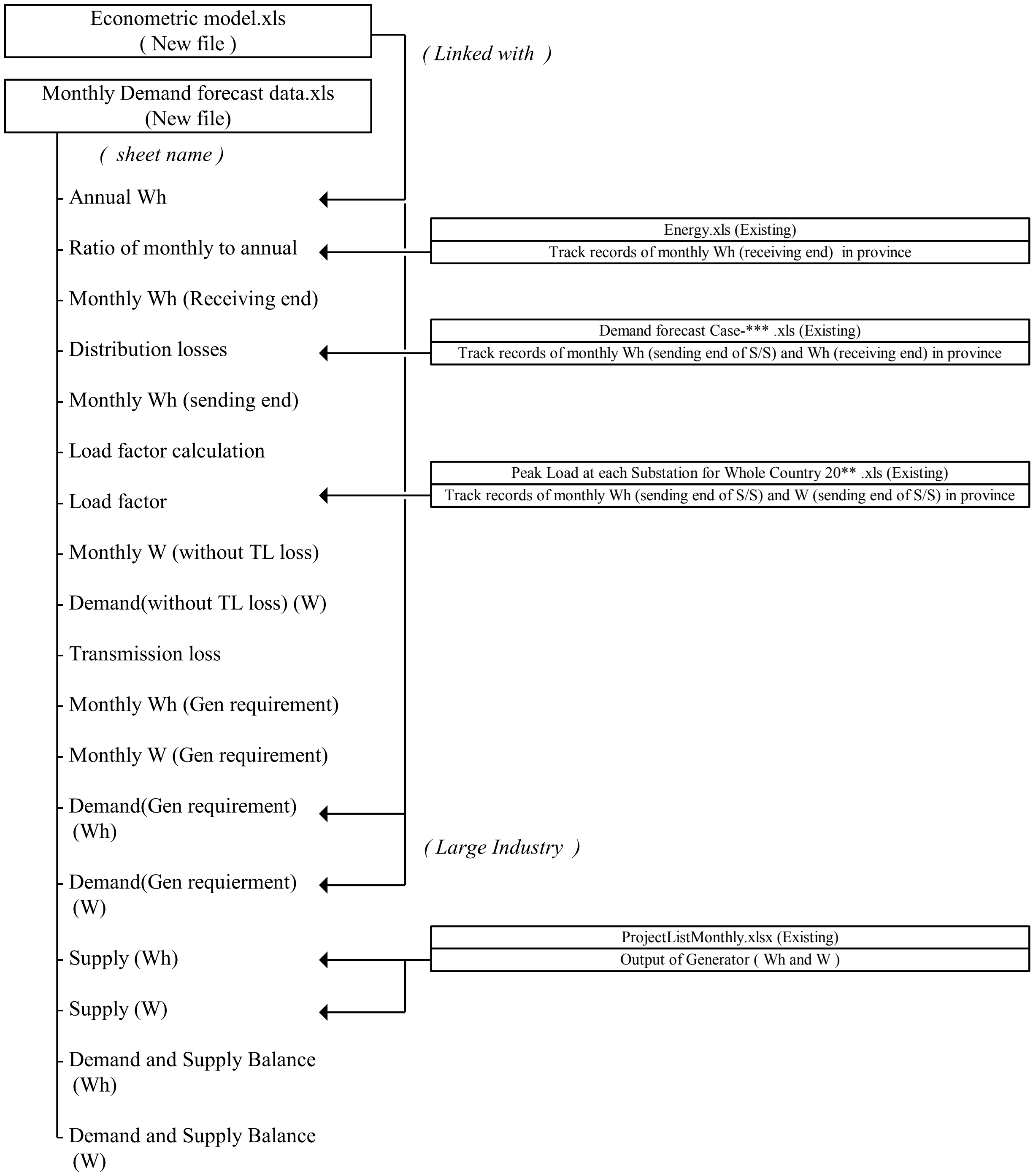
Monthly load factor is calculated from the track records of Wh (sending end) and W (sending end). Study Team assumes the load factor between 2012 and 2030 would increase linearly. In addition, the Study Team defines the target of monthly load factor in 2030 as 75%, which are the same as those in the PDP 2010-2020. Defining the averaged load factor of 2010 and 2011 as the starting point and that of 2030 (75%) as the other end, the coefficient (load factor increase/year) between 2012 and 2030 is determined by the linear interpolation. With the availability of the more track records in the future, more precise calculation can be conducted by using the spreadsheet which performs the linear interpolation.

5) Area of demand and balance sheet

In order to check the balance between EGAT and Laos system, demand and supply balance sheet is designed to calculate separately each one of two areas, since the current system configuration consists of two areas.

3.1.5 File system

The file system which uses links of EXCEL is formed for monthly demand supply calculation.

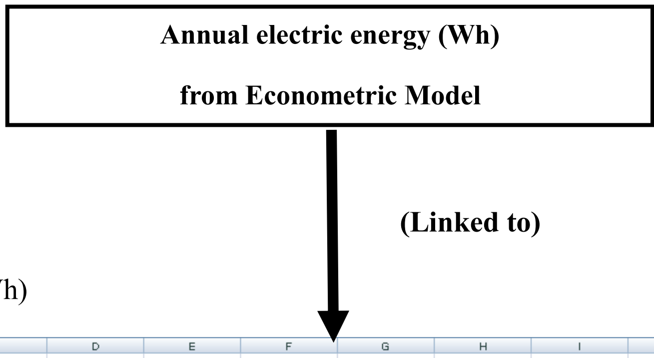


(Source : Study Team)

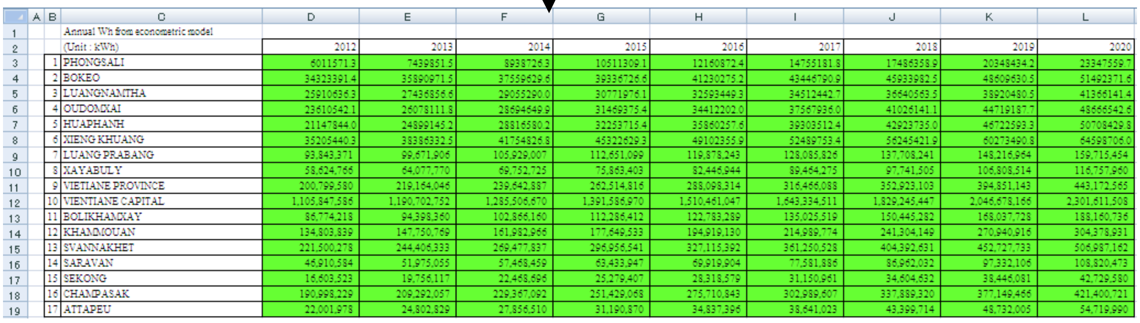
Figure 3-2 : File system for monthly demand and supply sheet

(1) Annual Wh sheet

This sheet has a link to annual electric energy calculated by using econometrics model.



(Sheet : Annual Wh)



Annual Wh from econometric model

(Unit : kWh)

	Province	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	PHONGSALI	6011571.3	7439851.5	8938726.3	10511309.1	12160872.4	14755181.8	17486358.9	20348434.2	23347559.7
2	BOKEO	34323391.4	35890971.5	37559629.6	39336726.6	41230275.2	43446790.9	45933982.5	48609630.5	51492371.6
3	LUANGNAMTHA	25910636.3	27436856.6	29055290.0	30771976.1	32593449.3	34512442.7	36640563.5	38920480.5	41366141.4
4	OUDOMXAI	23610542.1	26078111.8	28694649.9	31469375.4	34412202.0	37567936.0	41026141.1	44719187.7	48666542.6
5	HUAPHANH	21147844.0	24899145.2	28816580.2	32253715.4	35860257.6	39303512.4	42923735.0	46722593.3	50708429.8
6	XIENG KHUANG	35205440.3	38386332.5	41754826.8	45322629.3	49102355.9	52489753.4	56245421.9	60273490.8	64598706.0
7	LUANG PRABANG	93,843,371	99,671,906	105,929,007	112,651,099	119,878,243	128,085,826	137,708,241	148,216,964	159,715,454
8	XAYABULY	58,624,766	64,077,770	69,752,725	75,863,403	82,446,944	89,464,275	97,741,505	106,808,514	116,757,960
9	VIETIANE PROVINCE	200,799,580	219,164,046	239,642,887	262,514,816	288,098,314	316,466,088	352,923,103	394,851,143	443,172,565
10	VIENTIANE CAPITAL	1,105,847,586	1,190,702,752	1,285,506,670	1,391,586,970	1,510,461,047	1,643,334,511	1,829,245,447	2,046,678,166	2,301,611,508
11	BOLIKHAMXAY	86,774,218	94,398,360	102,866,160	112,286,412	122,783,289	135,025,519	150,445,282	168,037,728	188,160,736
12	KHAMMOUAN	134,803,839	147,750,769	161,982,966	177,649,533	194,919,130	214,989,774	241,304,149	270,940,916	304,378,931
13	SVANNAKHET	221,500,278	244,406,333	269,477,837	296,956,541	327,115,392	361,250,528	404,392,631	452,727,733	506,987,162
14	SARAVAN	46,910,584	51,975,055	57,468,459	63,433,947	69,919,904	77,581,886	86,962,032	97,332,106	108,820,473
15	SEKONG	16,603,523	19,756,117	22,468,696	25,279,407	28,318,579	31,150,961	34,604,632	38,446,081	42,729,580
16	CHAMPASAK	190,998,229	209,292,057	229,367,092	251,429,068	275,710,843	302,989,607	337,889,320	377,149,466	421,400,721
17	ATTAPEU	22,001,978	24,802,829	27,856,510	31,190,870	34,837,396	38,641,023	43,399,714	48,732,005	54,719,990

(Source : Study Team)

Figure 3-3 : Annual Wh from econometric model

(2) Ratio of monthly to annual (Wh) sheet

This sheet tells the ratio to allocate the electric energy demand per year which is calculated by using econometrics model to the electric energy demand per month.

In addition, this sheet has a link to the monthly actual electric energy at receiving end (electric energy sold) for each province (Excel file name:energy.xls) made by EDL for the past five years. Using the data, the ratio of monthly electric energy demand for each month to annual electric energy demand can be calculated. In this study, past five year average is applied as the ratio.

(Excel file [energy.xls] by EDL)

	A	B	C	D	E	F	G	H	I	J	K	L
1	VT Cap											
2	No	Load Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
3	1	Residential	29,531,891	26,605,683	31,297,613	35,594,784	41,350,288	40,987,128	42,750,696	40,639,518	42,663,412	40,327,540
4	2	Embassy	606,140	624,024	672,974	827,116	923,211	890,402	856,579	805,052	869,145	806,110
5	3	Business	7,717,021	8,280,858	10,475,459	10,626,662	11,530,850	12,846,045	255,398	12,147,648	12,159,793	11,776,440
6	4	Entertain	153,066	174,897	238,244	230,396	231,608	315,112	247,331	254,416	248,195	200,690
7	5	Government office	4,467,263	5,024,868	6,978,741	7,019,955	8,131,152	9,318,501	8,803,521	8,407,587	8,537,139	7,988,717
8	6	Agriculture	3,745,506	4,277,230	4,129,707	3,005,531	505,601	516,535	694,835	84,545	30,126	264,315
9	7	Industry	23,557,636	23,261,428	25,231,959	22,262,702	29,000,049	30,363,217	27,661,528	30,826,796	28,348,249	30,314,676
10	8	**Total**	**69,778,523**	**68,248,988**	**79,024,697**	**79,567,146**	**91,672,759**	**95,236,940**	**81,269,888**	**93,165,562**	**92,856,059**	**91,678,488**
11												
12	VT Pro											
13	No	Load Sector	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
14	1	Residential	5,817,041	5,418,268	5,439,596	6,337,614	7,083,382	7,102,330	6,990,292	6,924,470	7,176,803	7,112,961

(Linked to)

(Sheet : Ratio of monthly to annual)

	A	B	C	D	E	F	G	H	I	J	K	L	M
55													
56			2011 actual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
57		1	PHONGSALI	249,617	195,117	186,842	228,117	[illegible]	299,877	302,826	320,489	328,707	315,073
58		2	BOKEO	3,150,082	2,872,400	2,683,733	3,092,352	[illegible]	3,539,568	3,530,671	3,484,709	3,606,326	3,653,087
59		3	LUANGNAMTHA	1,586,333	1,544,605	1,694,689	1,993,210	[illegible]	2,255,226	2,132,918	2,156,461	2,251,997	2,094,890
60		4	OUDOMXAI	1,752,331	1,777,037	1,837,121	1,814,192	[illegible]	2,070,509	1,914,794	2,111,896	2,152,449	2,083,085
61		5	HUAPHANH	1,005,608	940,023	1,031,826	1,019,652	[illegible]	1,069,340	995,674	977,507	1,180,024	1,133,767
62		6	XIENG KHUANG	2,717,559	2,683,235	2,720,665	2,946,647	[illegible]	2,926,357	2,133,765	1,962,692	1,749,372	2,353,431
63		7	LUANG PRABANG	6,863,853	6,411,505	7,793,925	7,603,095	[illegible]	8,027,384	8,306,455	8,227,734	7,937,843	8,009,532
64		8	XAYABULY	4,201,912	4,109,492	4,401,870	4,795,548	[illegible]	4,923,866	4,752,127	4,857,296	5,213,425	4,655,056
65		9	VIETIANE PROVINCE	37,874,704	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39,361,669	37,981,405
66		10	VIENTIANE CAPITAL	69,778,523	68,248,988	79,024,697	79,567,146	91,672,759	95,236,940	81,269,888	93,165,562	92,856,059	91,678,488
67		11	BOLIKHAMXAY	6,627,694	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7,400,358	7,406,251
68		12	KHAMMOUAN	14,308,655	14,567,842	15,955,033	16,800,030	[illegible]	14,596,241	16,857,190	15,691,565	15,623,058	18,550,669

(Automatically calculated)

(Sheet : Ratio of monthly to annual)

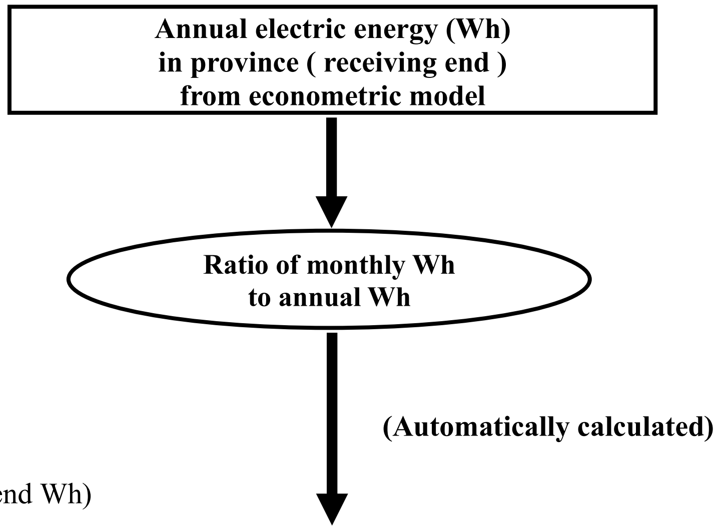
	A	B	C	D	E	F	G	H	I	J	K	L	M
1			Ratio of annual Wh to monthly Wh										
2			(average of resent 5 years)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
3		1	PHONGSALI	0.076	0.074	0.062	0.069	0.076	0.087	0.094	0.092	0.093	0.092
4		2	BOKEO	0.074	0.068	0.065	0.075	0.084	0.086	0.085	0.090	0.094	0.096
5		3	LUANGNAMTHA	0.069	0.065	0.070	0.076	0.088	0.090	0.087	0.092	0.097	0.092
6		4	OUDOMXAI	0.069	0.087	0.068	0.088	0.074	0.087	0.093	0.084	0.092	0.089
7		5	HUAPHANH	0.079	0.076	0.078	0.080	0.081	0.080	0.081	0.085	0.092	0.090
8		6	XIENG KHUANG	0.081	0.070	0.082	0.085	0.085	0.086	0.077	0.082	0.084	0.085
9		7	LUANG PRABANG	0.073	0.070	0.075	0.082	0.089	0.092	0.092	0.092	0.089	0.087
10		8	XAYABULY	0.074	0.072	0.081	0.086	0.086	0.089	0.090	0.090	0.089	0.087
11		9	VIETIANE PROVINCE	0.075	0.073	0.074	0.072	0.086	0.090	0.084	0.084	0.094	0.091
12		10	VIENTIANE CAPITAL	0.071	0.070	0.078	0.084	0.091	0.089	0.088	0.088	0.088	0.087
13		11	BOLIKHAMXAY	0.077	0.078	0.075	0.089	0.088	0.086	0.081	0.085	0.087	0.087
14		12	KHAMMOUAN	0.081	0.079	0.085	0.093	0.086	0.084	0.083	0.080	0.086	0.080

(Source : Study Team)

Figure 3-4 : Ratio of monthly to annual electric energy

(3) Monthly Wh (Receiving end) sheet

The electric energy (receiving end) per month for each province from 2012 to 2020 is calculated by using the ratio of monthly electric energy to annual electric energy for each month.



(Sheet : Receiving end Wh)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2			Receiving end Wh	2012									
3			(Unit : kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
4		1	PHONGSALI	457360	443502	373358	416637	454779	523341	565862	550404	560569	552006
5		2	BOKEO	2541443	2332498	2247894	2579647	2895028	2952147	2916637	3075739	3210449	3278223
6		3	LUANGNAMTHA	1796845	1695043	1802118	1963752	2292843	2336034	2266442	2392903	2511438	2392049
7		4	OUDOMXAI	1617720	2064955	1612263	2068645	1751924	2053894	2198464	1985160	2173360	2108219
8		5	HUAPHANH	1671657	1598420	1645507	1701933	1706210	1684399	1717864	1799546	1942829	1912659
9		6	XIENG KHUANG	2849694	2474880	2889914	2985778	3003543	3029006	2706810	2872162	2963017	3006335
10		7	LUANG PRABANG	6869475	6542529	7056441	7694891	8395747	8598656	8649577	8642102	8340709	8127054
11		8	XAYABULY	4319522	4235090	4743795	5016990	5029721	5223042	5296120	5304347	5214101	5096693
12		9	VIETIANE PROVINCE	15009741	14567397	14929178	14505473	17195963	18081467	16776607	16769720	18968188	18202763
13		10	VIENTIANE CAPITAL	78739213	77825841	86270494	92509980	100688995	98738127	97555185	97688817	96856246	96384385
14		11	BOLIKHAMXAY	6699836	6771260	6491075	7758505	7622181	7494574	7063866	7379571	7571510	7516807
15		12	KHAMMOUAN	10898522	10640694	11496198	12580623	11554411	11340849	11234660	10757466	11595411	10760278

(Source : Study Team)

Figure 3-5 : Monthly electric energy (Wh) (Receiving end) from 2012 to 2020

(4) Distribution loss sheet

This sheet calculates the distribution loss rate. The current distribution loss rate is calculated by using the annual electric energy at the receiving end for each province and actual annual electric energy at the sending end of substation.

The future distribution loss rate is calculated by using linear interpolation which EDL uses for demand forecast in PDP 2010-2020, and it is assumed that the distribution loss rate will be diminished to 6.0% by year 2030.

(Sheet : Distribution loss)

Distribution loss of EdL's branches (January to December 2010)

No.	EDL Branch	Sent out from Substation	Received from Bills (Customer)	Distribution losses	
		KWh	KWh	KWh	%
1	Phonsaly	2,[illegible]61,922	2,159,033	202,889	8.6
2	Bokeo	35,409,983	31,[illegible]8,229	3,951,754	11.16
3	Louangnamtha	24,473,982	23,103,[illegible]39	1,370,543	5.60
4	Oudomxay	20,590,472	18,399,6[illegible]	2,190,826	10.64
5	Houaphan	13,257,778	11,356,613	1,901,165	14.34
6	Xiengkhouang	31,238,011	28,348,495	2,889,516	9.25
7	Louangprabang	91,134,833	83,324,578	7,810,255	8.57
8	Xaygnabouly	55,603,801	48,770,094	6,833,707	12.29
9	Vientiane Province	449,745,799	423,930,390	25,815,409	5.74
10	Vientiane Capital	1,090,163,429	960,652,014	129,511,415	11.88
11	Bolikhamxay	84,627,455	73,659,737	10,9[illegible]7,718	12.96
12	Khammouan	184,153,291	160,880,816	23,272,475	12.64
13	Savannakhet	539,413,901	470,367,234	69,046,668	12.80
14	Salavan	44,932,493	37,896,0[illegible]	7,036,428	15.6[illegible]
15	Xekong	12,047,146	10,958,[illegible]84	1,089,062	9.04
16	Champasak	176,697,467	159,[illegible]0,051	17,687,416	10.01
17	Attapeu	1[illegible]13,905	[illegible]7,054,959	1,358,946	7.38
		2,874,265,67[illegible]	2,561,329,477	312,936,194	10.89

<u>Input the data</u> of
sending end Wh and receiving end Wh

(Automatically calculated)

(Sheet : Distribution loss)

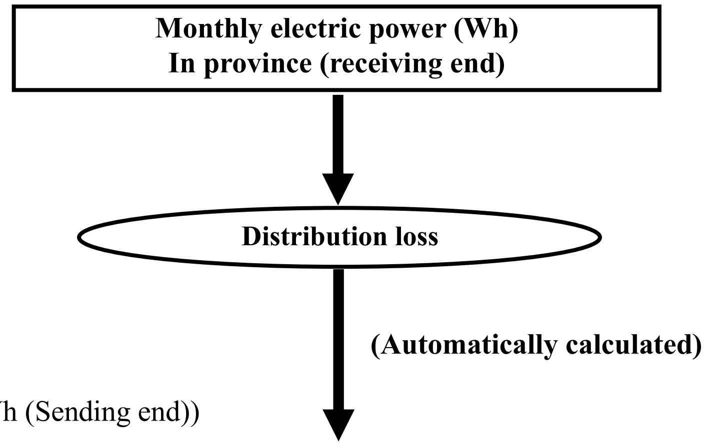
	Distribution loss [%]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Phonsaly	8.6	8.5	8.3	8.2	8.1	7.9	7.8	7.7	7.6	7.4	7.3
2	Bokeo	11.2	10.9	10.6	10.4	10.1	9.9	9.6	9.4	9.1	8.8	8.6
3	Louangnamtha	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.8	5.8	5.8
4	Oudomxay	10.6	10.4	10.2	9.9	9.7	9.5	9.2	9.0	8.8	8.6	8.3
5	Houaphan	14.3	13.9	13.5	13.1	12.7	12.3	11.8	11.4	11.0	10.6	10.2
6	Xiengkhouang	9.3	9.1	8.9	8.8	8.6	8.4	8.3	8.1	8.0	7.8	7.6
7	Louangprabang	8.6	8.4	8.3	8.2	8.1	7.9	7.8	7.7	7.5	7.4	7.3
8	Xaygnabouly	12.3	12.0	11.7	11.3	11.0	10.7	10.4	10.1	9.8	9.5	9.1
9	Vientiane Province	5.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9
10	Vientiane Capital	11.9	11.6	11.3	11.0	10.7	10.4	10.1	9.8	9.5	9.2	8.9
11	Bolikhamxay	13.0	12.6	12.3	11.9	11.6	11.2	10.9	10.5	10.2	9.8	9.5

(Source : Study Team)

Figure 3-6 : Distribution loss [%] from 2012-2020

(5) Monthly Wh (Sending end) sheet

This sheet calculates monthly electric energy (substation sending end) which includes distribution loss.



(Sheet : Monthly Wh (Sending end))

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2			Monthly amount of electric power	2012									
3			without TL loss (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
4		1	PHONGSALI	500339	485179	408443	455789	497515	572520	619038	602126	613246	603879
5		2	BOKEO	2860697	2625504	2530273	2903700	3258699	3322993	3283022	3462110	3613743	3690030
6		3	LUANGNAMTHA	1903437	1795596	1909024	2080246	2428859	2474613	2400892	2534855	2660422	2533950
7		4	OUDOMXAI	1810340	2310827	1804233	2314957	1960523	2298449	2460233	2221530	2432140	2359243
8		5	HUAPHANH	1951503	1866005	1920975	1986847	1991840	1966378	2005444	2100801	2268070	2232850
9		6	XIENG KHUANG	3140159	2727140	3184478	3290113	3309690	3337748	2982711	3164917	3265033	3312766
10		7	LUANG PRABANG	7513371	7155780	7717861	8416155	9182705	9404633	9460327	9452151	9122508	8888826
11		8	XAYABULY	4924778	4828514	5408499	5719975	5734490	5954899	6038217	6047597	5944705	5810846
12		9	VIETIANE PROVINCE	15923765	15454484	15838296	15388790	18243118	19182545	17798225	17790918	20123264	19311227
13		10	VIENTIANE CAPITAL	89354531	88318022	97901151	104981820	114263499	112049622	110707200	110858848	109914033	109378558
14		11	BOLIKHAMXAY	7697422	7779480	7457577	8913724	8757101	8610494	8115654	8478368	8698886	8636038

(Source : Study Team)

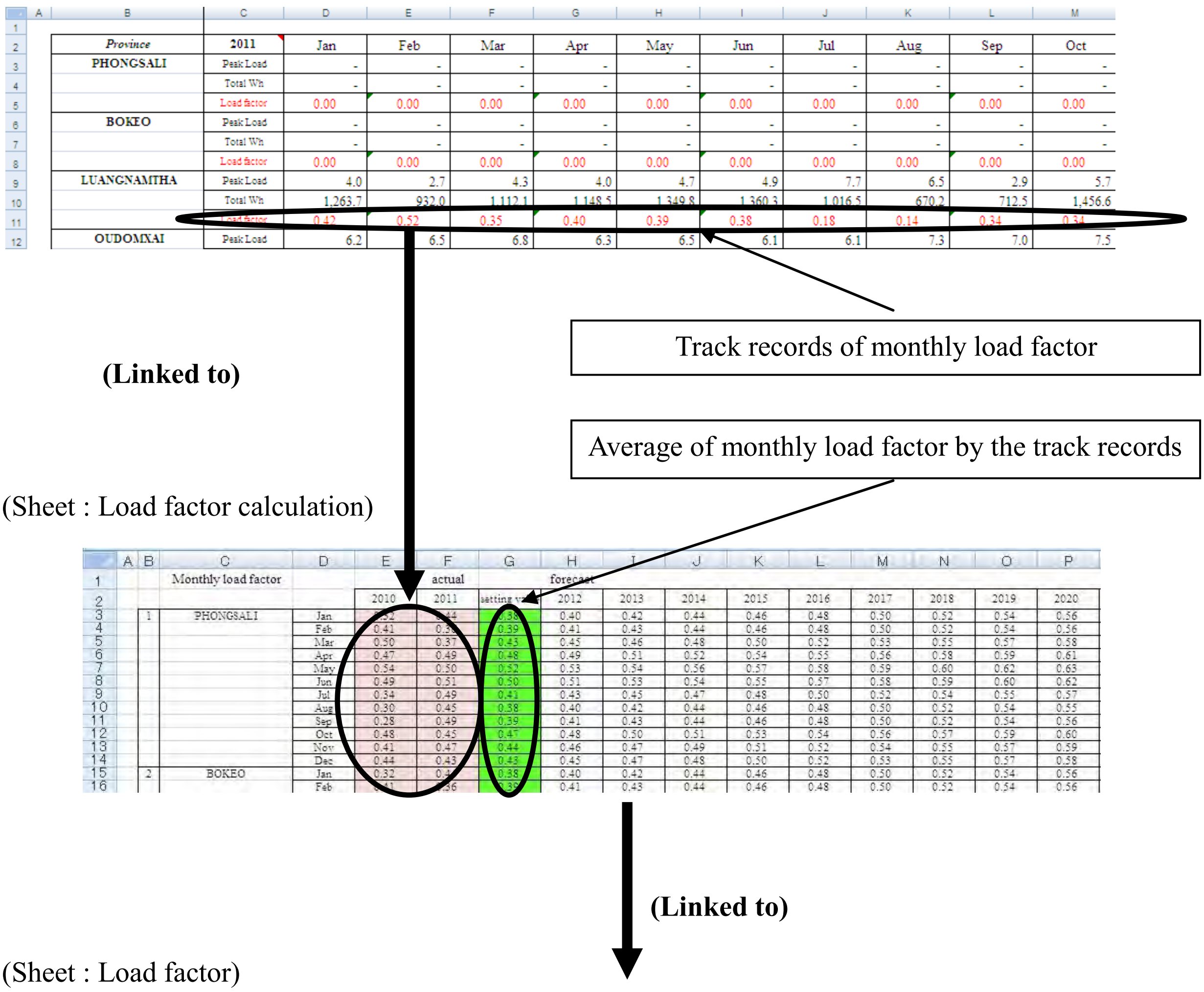
Figure 3-7 : Monthly electric energy (Wh) (Sending end of S/S) in each province

(6) Load factor calculation, Load factor sheet

This sheet calculates monthly load factor for each province.

Using the data of the actual load factor for each substation (Excel file name: Peak Load at each Substation for Whole country 20**.xls) made by EDL, monthly maximum demand for each province and monthly electric energy are calculated. The actual load factor in the past is calculated by using this monthly maximum electric energy demand and monthly electric energy. The actual load factor in the past is linked to and output by Excel sheet. This time, the Study Team figured out the monthly load factor by using the actual demand data of 2010 and 2011, and defined the averaged number as the load factor in the future. For the future when being able to accumulate the data for several years, the excel sheet is such a format that can be linearly interpolated future monthly load factor from current to 2030.

([Peak Load at each Substation for Whole Country 20** .xls (Existing)**.xls] by EDL)



(Sheet : Load factor)

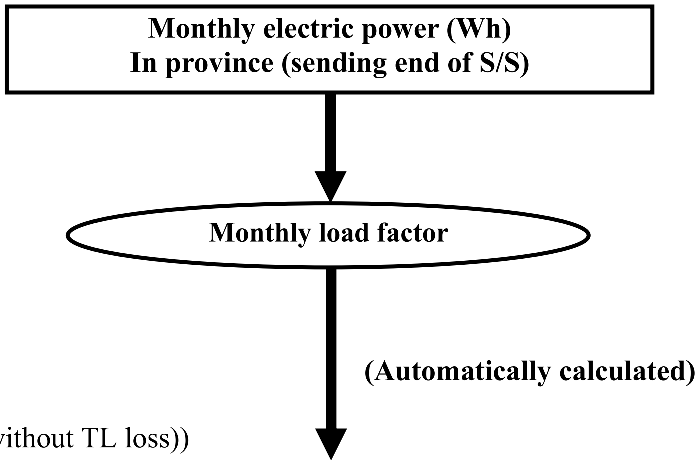
	Monthly load factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	2012										
1	PHONGSALI	0.40	0.41	0.45	0.49	0.53	0.51	0.43	0.40	0.41	0.48
2	BOKEO	0.40	0.41	0.45	0.49	0.53	0.51	0.43	0.40	0.41	0.48
3	LUANGNAMTHA	0.40	0.41	0.45	0.49	0.53	0.51	0.43	0.40	0.41	0.48
4	OUDOMXAI	0.40	0.41	0.45	0.49	0.53	0.51	0.43	0.40	0.41	0.48
5	HUAPHANH	0.45	0.47	0.35	0.46	0.44	0.44	0.44	0.46	0.45	0.46
6	XIENG KHUANG	0.54	0.52	0.51	0.53	0.54	0.54	0.50	0.50	0.49	0.50
7	LUANG PRABANG	0.54	0.55	0.56	0.59	0.58	0.61	0.60	0.57	0.50	0.54
8	XAYABULY	0.54	0.56	0.58	0.58	0.61	0.60	0.59	0.58	0.58	0.56
9	VIETIANE PROVINCE	0.61	0.57	0.57	0.61	0.60	0.59	0.53	0.61	0.58	0.64

(Source : Study Team)

Figure 3-8 : Monthly load factor from 2012 to 2020

(7) Monthly W (Without TL loss) sheet

This sheet figures out the monthly peak load (sending end of substation) by using the data of monthly electric energy (Sending end of substation) and monthly load factor.



(Sheet : Monthly W (without TL loss))

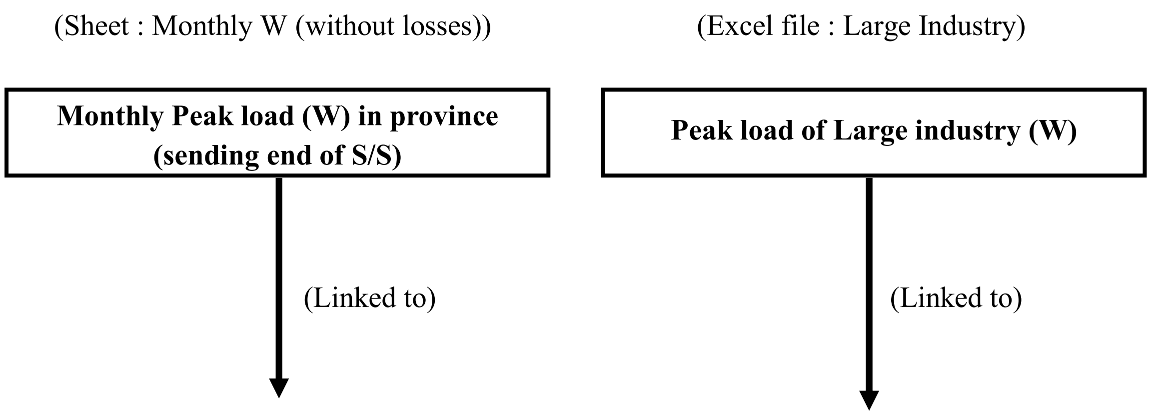
	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2			Monthly peak load	2012									
3			without TL loss (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
4		1	PHONGSALI	1.67	1.78	1.22	1.28	1.26	1.55	1.93	2.03	2.10	1.68
5		2	BOKEO	9.56	9.61	7.59	8.17	8.25	9.00	10.26	11.67	12.35	10.25
6		3	LUANGNAMTHA	6.36	6.57	5.72	5.85	6.15	6.70	7.50	8.54	9.09	7.04
7		4	OUDOMXAI	6.05	8.46	5.41	6.52	4.96	6.23	7.69	7.49	8.31	6.55
8		5	HUAPHANH	5.83	5.95	7.32	5.95	6.02	6.24	6.06	6.08	6.99	6.57
9		6	XIENG KHUANG	7.77	7.77	8.47	8.68	8.23	8.63	7.94	8.58	9.17	8.87
10		7	LUANG PRABANG	18.74	19.35	18.37	19.76	21.37	21.51	21.19	22.37	25.46	22.33
11		8	XAYABULY	12.32	12.79	12.60	13.79	12.69	13.76	13.71	14.09	14.19	13.86
12		9	VIETIANE PROVINCE	35.22	40.35	37.58	35.23	41.01	45.54	45.29	39.26	48.48	40.61
13		10	VIENTIANE CAPITAL	203.66	206.85	209.10	224.90	243.16	232.16	237.07	232.68	251.31	261.39
14		11	BOLIKHAMXAY	16.89	19.19	15.71	19.52	18.53	18.32	17.73	18.26	20.12	18.88

(Source : Study Team)

Figure 3-9 : Monthly W (without TL loss) in province

(8) Demand (Without TL loss) sheet

This sheet figures out the monthly peak load of each substation and large industry. The peak load for each province which is calculated by using the Excel sheet Monthly W (Without TL loss) is allocated to each substation accordingly with the actual ratio.



(Sheet : Demand (without TL loss) (W))

Table : Substation Peak Load Forecasts (MW)

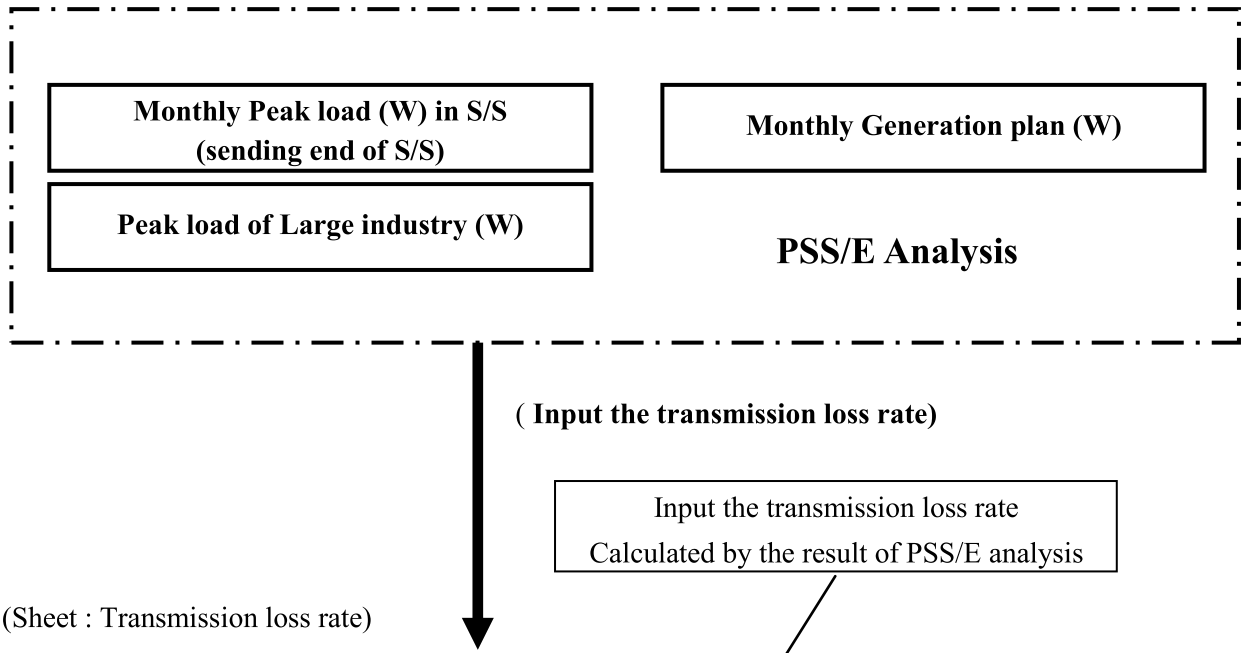
	Provinces	No.	Name of Substations			Com. years	2012	2012	2012	2012	2012	2012	2012	2012	2012
							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	PHONGSALI		Sub Total				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		I.	Residential Sector				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		1	Boun Neua	1116		2013									
		1.1	Copper Mining 1 at Yot Ou District	1214	1	2015	-	-	-	-	-	-	-	-	
		1.2	Copper Mining 2 at Yot Ou District	1214	2	2016	-	-	-	-	-	-	-	-	
			Total Load during Construction of Hydro Power Plants			2014	-	-	-	-	-	-	-	-	
2	BOKEO		Sub Total				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		I.	Residential Sector				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		1	Houayxay	1118		2014									
			Dokngiewkham	1250		2013	-	-	-	-	-	-	-	-	
			Total Load during Construction of Hydro Power Plants												
3	LUANGNAMTHA		Sub Total				3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3
		I.	Residential Sector				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		1	Luangnamtha 1	1109		2009	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
			Copper Mining at Houay Mo, Long District	1208	1	2012	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
		2	Luangnamtha 2	1125		2014									
			Total Load during Construction of Hydro Power Plants			2011	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1

(Source : Study Team)

Figure 3-10 : Monthly Peak Load (W) of each S/S without TL loss

(9) Transmission loss rate sheet

The transmission loss rate is calculated by the analysis result of the software PSS/E. The analysis is performed using the data of demand of each substation and Large industry, and monthly generation plan in each power station. In doing this, the transmission loss rate needs to be calculated by separating two blocks of power system, which are North-middle and South. Then, sum up those to each load as averaged loss rate for each block. After 2014 when the two systems will be connected, transmission loss will be calculated as one whole power system loss and the loss rate is added to each load.



TL loss [%]

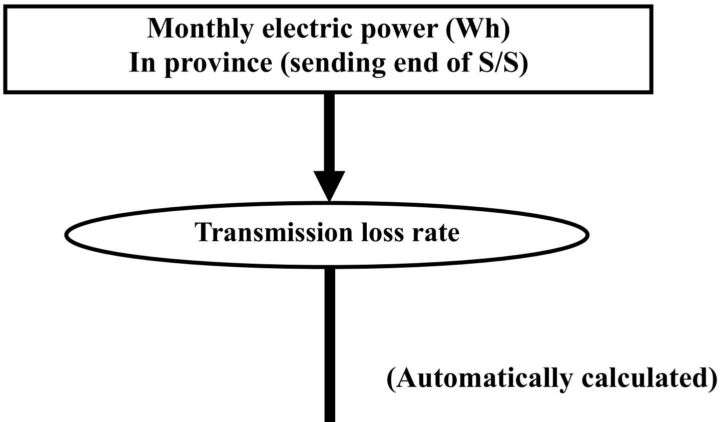
	2012	2013	2014	2015	2016	2017	2018	2019	202
Phonsaly	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Bokeo	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Louangnamtha	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Oudomxay	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Houaphan	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Xiengkhouang	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Louangprabang	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Xaygnabouly	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vientiane Province	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vientiane Capital	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Bolikhamxay	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

(Source : Study Team)

Figure 3-11 : Transmission loss rate

(10) Monthly Wh (Gen requirement) sheet

This sheet tells the electric energy per month at sending end of substation by using the data of Monthly electric energy (Wh) (Sending end of S/S) and monthly load ratio for each province.



(Sheet : Monthly Wh (Gen requirement))

		Monthly amount of electric power with TL losses (kWh)	2012									
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	PHONGSALI		518487	502776	423257	472320	515560	593285	641490	623965	635489	625782
2	BOKEO		2964452	2720729	2622044	3009015	3376890	3443516	3402095	3587679	3744812	3823866
3	LUANGNAMTHA		1972474	1860721	1978263	2155695	2516953	2564365	2487971	2626793	2756914	2625855
4	OUDOMXAI		1876000	2394639	1869672	2398919	2031630	2381812	2549464	2302104	2520353	2444811
5	HUAPHANH		2022283	1933684	1990648	2058909	2064083	2037697	2078181	2176996	2350331	2313834
6	XIENG KHUANG		3254051	2826052	3299978	3409444	3429730	3458806	3090892	3279706	3383454	3432918
7	LUANG PRABANG		7785876	7415316	7997784	8721404	9515756	9745734	9803448	9794975	9453376	9211219
8	XAYABULY		5103396	5003642	5604663	5927435	5942476	6170880	6257219	6266940	6160316	6021602
9	VIETIANE PROVINCE		16501311	16015010	16412742	15946932	18904785	19878285	18443756	18436185	20853123	20011635
10	VIENTIANE CAPITAL		92595369	91521267	101451970	108789451	118407771	116113598	114722487	114879636	113900553	113345656
11	BOLIKHAMXAY		7976603	8061637	7728059	9237020	9074716	8922791	8410004	8785874	9014390	8949262

(Source : Study Team)

Figure 3-12 : Monthly demand (Wh) in province (Generation requirement)

(11) Monthly W (Without TL loss) sheet

This sheet tells the electric energy per month (generation requirement) of Large industry for each substation. The monthly electric energy (Wh) calculated by using the Monthly Wh (Gen requirement) sheet is allocated accordingly with the actual ratio to each substation.

(Sheet : Monthly Wh (Gen requirement))　　　　　(Excel file [Large industry.xls])

(Sheet : Demand(Gen requirement) (Wh))

Substation Load Forecasts (GWh)

	Provinces	No.	Name of Substations			Com. years	2012	2012	2012	2012
							Jan	Feb	Mar	Apr
1	PHONGSALI		Sub Total				0.5	0.5	0.4	0.5
		I.	Residential Sector				0.5	0.5	0.4	0.5
			1 Boun Neua	1116		2013				
			1.1 Copper Mining 1 at Yot Ou District	1214	1	2015	0.0	0.0	0.0	0.0
			1.2 Copper Mining 2 at Yot Ou District	1214	2	2016	0.0	0.0	0.0	0.0
			Total Load during Construction of Hydro Power Plants			2014	0.0	0.0	0.0	0.0
2	BOKEO		Sub Total				3.0	2.7	2.6	3.0
		I.	Residential Sector				3.0	2.7	2.6	3.0
			1 Houayxay	1118		2014				
			Dokngiewkham	1250		2013	0.0	0.0	0.0	0.0
			Total Load during Construction of Hydro Power Plants							
3	LUANGNAMTHA		Sub Total				7.1	7.0	7.1	7.3
		I.	Residential Sector				2.0	1.9	2.0	2.2
			1 Luangnamtha 1	1109		2009	2.0	1.9	2.0	2.2
			Copper Mining at Houay Mo, Long District	1208	1	2012	4.7	4.7	4.7	4.7
			2 Luangnamtha 2	1125		2014				
			Total Load during Construction of Hydro Power Plants			2011	0.4	0.4	0.4	0.4
			Economic Spacial Zone (Boten)	1208	s	2013				
			Railway station			2015				
			Train running	1208	T	2015				
4	OUDOMXAI		Sub Total				29.4	29.9	29.4	29.9
		I.	Residential Sector				1.9	2.4	1.9	2.4
			1 Oudomxay	1206		2009	1.3	1.7	1.3	1.7
			Iron melting factory, at Phu Phan Village, La District	1108		2015	0.0	0.0	0.0	0.0
			2 Namo	1107		2012	0.6	0.7	0.6	0.7
			Cement Factory at Thong Na Village, Namo District	1207	1	2012	4.7	4.7	4.7	4.7
			Copper Mining at Kiew Chep Village, Namo District	1207	3	2015	0.0	0.0	0.0	0.0

(Source : Study Team)

Figure 3-13 : Monthly electric energy (Wh) in each S/S (Generation requirement)

(12) Supply (Wh) sheet

This sheet has a link to Monthly electric energy (Wh) of generation made by EDL.

Monthly electric power (Wh)
from generation planning
(Excel file name : [ProjectlistMonthly.xls])

(Linked to)

(Sheet : Supply(Wh))

Power station (GWh)

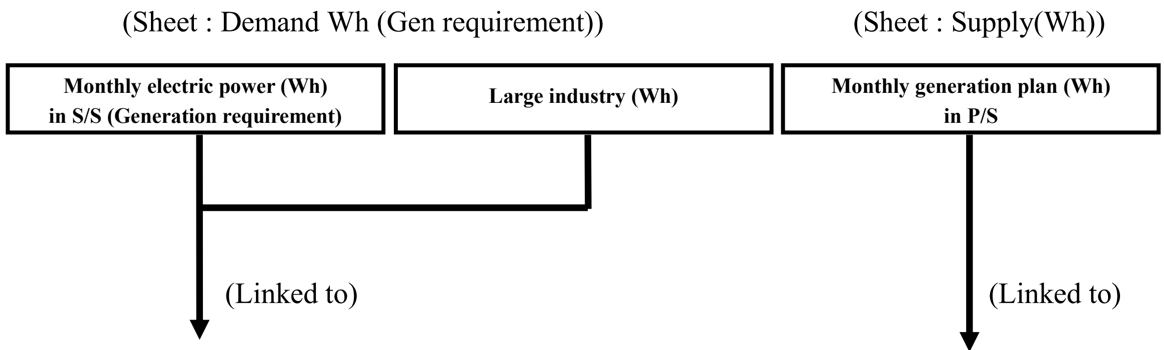
	Provinces	No.	Name of Substations	PSSE Bus No	ID		Com. years	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug
1	PHONGSALI		Sub Total					0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
		1	Nam Ngay			009LE	2006	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
			NGAY	1005	1			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
			NGAY	1006	2			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
		1	Nam Boun 2			038LN	2014	-	-	-	-	-	-	-	-
			NBU2	1027	1			-	-	-	-	-	-	-	-
			NBU2	1028	2			-	-	-	-	-	-	-	-
		1	Nam Ou 5			068DN	2016	-	-	-	-	-	-	-	-
			NOU5	1054	1			-	-	-	-	-	-	-	-
			NOU5	1055	2			-	-	-	-	-	-	-	-
		1	Nam Ou 6			069DN	2016	-	-	-	-	-	-	-	-
			NOU6	1056	1			-	-	-	-	-	-	-	-
			NOU6	1057	2			-	-	-	-	-	-	-	-
			NOU6	1058	3			-	-	-	-	-	-	-	-
		1	Nam Ou 4			083DN	2018	-	-	-	-	-	-	-	-
			NOU4	1052	1			-	-	-	-	-	-	-	-
			NOU4	1053	2			-	-	-	-	-	-	-	-

(Source : Study Team)

Figure 3-14 : Supply(Wh) of generation by EDL's planning list

(13) Demand and Supply balance sheet

This sheet forms demand and supply balance. The power system in Laos consists of two areas, which are North-middle and South, each of which is interconnected to EGAT. Therefore, monthly demand and generation are summed up separately for each power system. Using this balance sheet, the monthly generation excess and deficiency (the amount of import and export) in the future can be confirmed.



(Sheet : Demand and Supply Balance(GWh))

Demand (GWh)

area	Demand	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug	2012 Sep	2012 Oct	2012 Nov	2012 Dec
1 North + Central		264	263	279	295	316	315	306	308	316	310	303	299
2 South		28	29	30	33	33	31	29	29	29	27	27	28
Total		292	292	309	328	349	346	336	336	345	337	330	327

area	2013 Jan	2013 Feb	2013 Mar	2013 Apr	2013 May	2013 Jun	2013 Jul	2013 Aug	2013 Sep	2013 Oct	2013 Nov	2013 Dec
1 North + Central	303	303	320	339	362	363	352	354	363	357	348	344
2 South	33	34	35	39	39	36	34	33	33	31	32	32
Total	336	337	355	377	401	398	387	387	397	388	380	376

area	2014 Jan	2014 Feb	2014 Mar	2014 Apr	2014 May	2014 Jun	2014 Jul	2014 Aug	2014 Sep	2014 Oct	2014 Nov	2014 Dec
1 North + Central	362	361	382	404	431	432	420	422	434	426	415	411
2 South	40	41	43	47	47	44	42	41	41	39	40	40
Total	402	403	424	451	478	476	462	463	474	465	455	451

Supply (GWh)

area	Suppply	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug	2012 Sep	2012 Oct	2012 Nov	2012 Dec
1 North + Central		244	232	224	216	246	278	390	474	457	353	251	244
2 South		20	15	13	13	28	48	63	99	118	100	70	20
Total		264	246	237	229	274	326	453	573	575	452	320	264

area	2013 Jan	2013 Feb	2013 Mar	2013 Apr	2013 May	2013 Jun	2013 Jul	2013 Aug	2013 Sep	2013 Oct	2013 Nov	2013 Dec
1 North + Central	256	244	236	227	259	298	419	507	488	375	269	258
2 South	29	23	21	22	36	60	78	115	134	113	81	29
Total	285	267	257	248	295	358	497	622	622	488	349	287

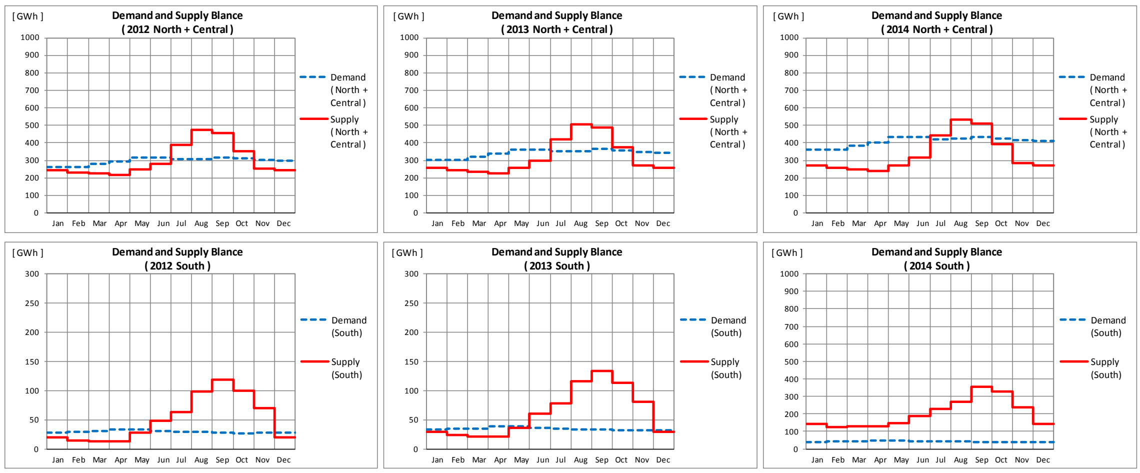
area	2014 Jan	2014 Feb	2014 Mar	2014 Apr	2014 May	2014 Jun	2014 Jul	2014 Aug	2014 Sep	2014 Oct	2014 Nov	2014 Dec
1 North + Central	270	255	247	238	271	315	441	531	512	393	284	270
2 South	143	126	131	127	148	186	227	271	354	328	237	143
Total	413	382	378	365	418	501	668	802	866	721	521	413

Balance (GWh)

area	Balance	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug	2012 Sep	2012 Oct	2012 Nov	2012 Dec
1 North + Central		(20)	(32)	(55)	(79)	(69)	(38)	84	167	140	42	(52)	(55)
2 South		(8)	(14)	(17)	(19)	(5)	17	34	70	90	73	42	(8)
Total		(28)	(46)	(72)	(99)	(75)	(21)	117	237	230	115	(10)	(63)

area	2013 Jan	2013 Feb	2013 Mar	2013 Apr	2013 May	2013 Jun	2013 Jul	2013 Aug	2013 Sep	2013 Oct	2013 Nov	2013 Dec
1 North + Central	(47)	(59)	(85)	(112)	(103)	(64)	67	153	125	18	(79)	(86)
2 South	(4)	(11)	(14)	(17)	(2)	24	44	82	101	81	49	(3)
Total	(51)	(69)	(98)	(129)	(106)	(40)	111	235	226	100	(30)	(89)

area	2014 Jan	2014 Feb	2014 Mar	2014 Apr	2014 May	2014 Jun	2014 Jul	2014 Aug	2014 Sep	2014 Oct	2014 Nov	2014 Dec
1 North + Central	(92)	(106)	(135)	(166)	(161)	(117)	21	109	78	(33)	(131)	(140)
2 South	103	85	88	80	101	142	185	230	313	289	197	103
Total	11	(21)	(47)	(86)	(60)	25	206	339	391	257	66	(37)



(Source : Study Team)

Figure 3-15 : Example of demand and supply balance sheet

3.2 Points of power system analysis

Transmission development planning is for the expansion of transmission lines and substations in accordance with demand increase and power development plan to supply high quality electricity to customers in low price.

Here, factors which are required for high quality electricity are:

- Few and short outages.
- Voltage and frequency within allowable range.
- No problems caused by flicker or harmonics.

However, the higher the power supply quality is, the higher the power supply cost becomes. High quality and low cost are contradictory to each other but these two should be balanced well.

The following diagram shows a basic concept of formulating the optimal power development plan.

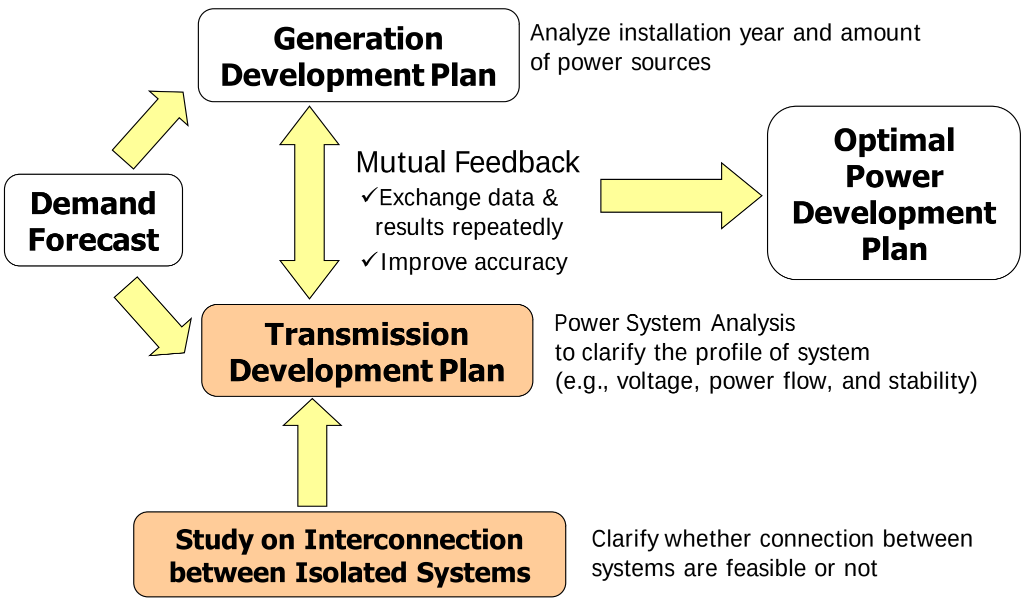


Figure 3-16 : Basic concept of formulating the power development plan

Types of power system analysis to formulate the optimal power development plan are described as below.

Table 3-1 : Types of power system analysis

Analysis	Description
Load Flow Analysis	Calculation of load flow to identify the bottle neck due to overloading.
Voltage Analysis	Analysis to identify whether voltage drop or collapse will occur or not
Short Circuit Capacity Calculation	Calculation of fault current (three-phase short circuit current) The three-phase short circuit current is usually larger than ground fault current, so the latter is usually omitted.
Stability Analysis	Study for checking the system stability after disturbance such as transmission line fault. There are two types of stability: state stability and transient stability.

(Source : Study Team)

3.2.1 Load flow analysis

Considering reliability is an important factor in transmission development. Generally, reliability is described quantitatively as below:

- The number of outages per consumer (numbers/year)
- Outage duration per consumer (minutes/year)

Practically, the N-1 standard is applied internationally for transmission development planning.

The N-1 standard is the optimal criterion as a target of reliability because:

- N-1 contingency is the most frequent among outages.
- It is necessary to have extra facilities in preparation for outages due to maintenance and repair.

Therefore, it is necessary not only to identify the bottle neck due to overloading, but also to confirm N-1standard is satisfied.

3.2.2 Voltage analysis

(1) Voltage problems and countermeasures

Voltage problems are categorized into two types; One is the voltage drop, which tends to happen during peak-load time because of heavy load. It is likely to occur at the end of grid. The other problem is voltage rise, which tends to happen during the off-peak time because of the Ferranti effect due to charging current. It is likely to occur in high voltage lines or cable grid. Countermeasures against each are shown below.

Note that synchronous capacitor is effective for both, but it is usually less economical and difficult to maintain.

Table 3-2 : Voltage problem and countermeasure

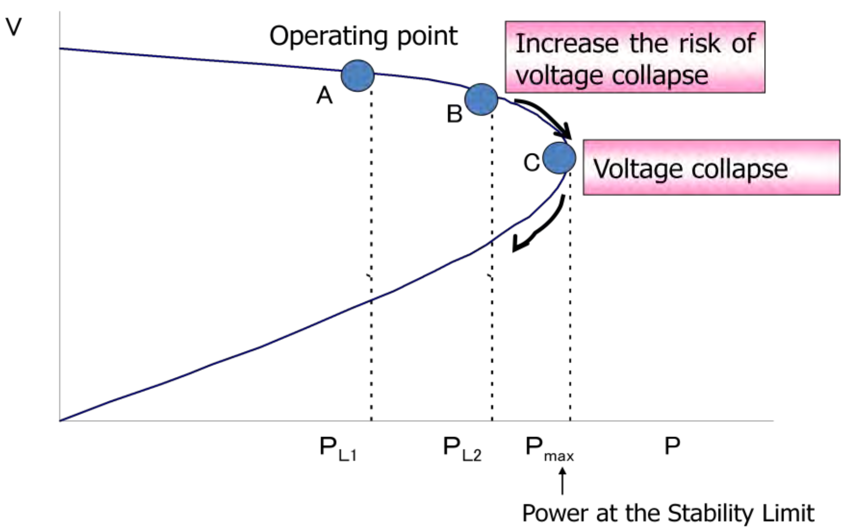
	Problem	Countermeasure	Remark
Peak time	Voltage falls down	1. Capacitor 2. Tap-changing control of transformer 3. Lagging phase operation of generator 4. Synchronous capacitor	Tends to happen at the end of the grid.
Off-peak time	Voltage rises up	1. Reactor 2. Tap-changing control of transformer 3. Leading phase operation of generator 4. Synchronous Capacitor	Tends to happen in High-voltage line or cable grid.

(Source : Study Team)

(2) Receiving power and voltage characteristic

This following figure shows the characteristic between receiving power and voltage characteristic, which is called P-V Curve or Nose Curve.

The top of the nose (Point C) shows the power at the stability limit. Though the power system is usually operated at Point A, a risk of voltage collapse would increase when the operation moves to the Point B. If the operating point went beyond the top of the nose (Point C), voltage collapse would occur. Thus, it is important for the system operation to be implemented with enough margins. The margin would get smaller when the transmission distance got longer or loading got heavier.



(Source : Study Team)

Figure 3-17 : Example of P-V Curve

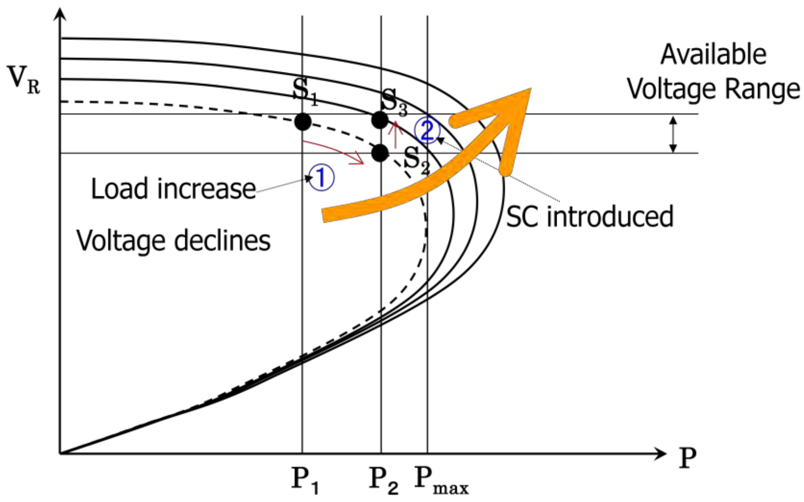
Countermeasures would be the following:

1) Installation of capacitor

2) Reinforcement of the transmission line

3) Installation of the generator near the load.

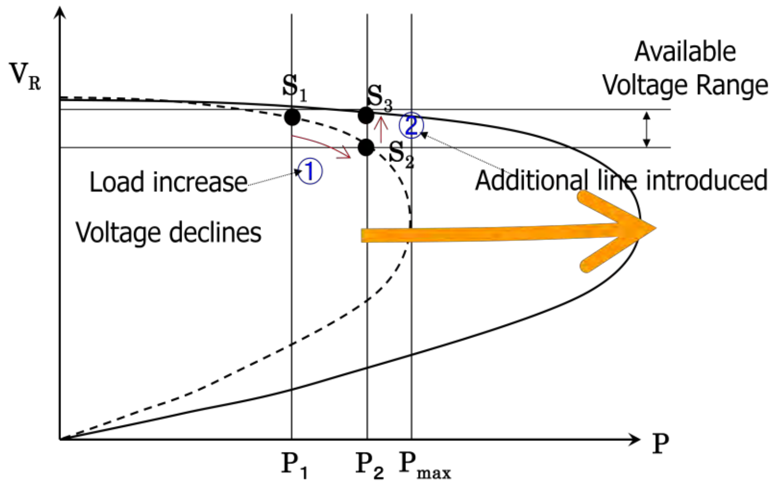
In case a static capacitor is installed, the P-V curve moves toward upper right direction as the following diagram shows. In a case like this, the voltage would be somewhat improved, however, the voltage may decline more easily as the load increases further. Thus, the installation of capacitor is a short term countermeasure.



(Source : Study Team)

Figure 3-18 : P-V curve moves toward upper right direction

In a case when additional transmission line is installed, the P-V curve moves toward the right direction as follows. In this case, even if load increased further, the voltage would not decline easily. This would work as a long-term countermeasure for a voltage problem.

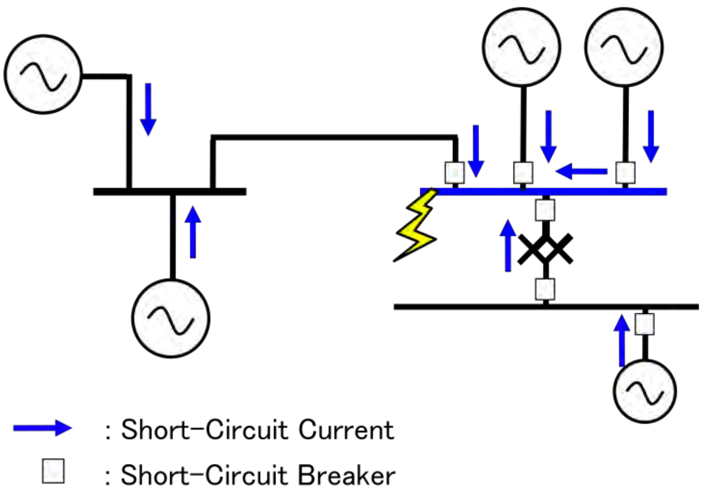


(Source : Study Team)

Figure 3-19 : P-V curve moves toward right direction

3.2.3 Short circuit analysis

During a normal state, a circuit breaker cuts off load current to maintain the power system. But if a short-circuit fault occurs, then a circuit breaker has to cut off the short circuit current. The short circuit current is much larger than load current. For this reason, the circuit breaker needs to have enough breaking capability.



(Source : Study Team)

Figure 3-20 : P-V curve moves toward right direction

As the diagram above shows, short circuit current comes from generators. Therefore, the short circuit current problem tends to occur where many generators and many transmission lines are concentrated.

(1) Problems of short-circuit current

The reasons for the increase of short-circuit current are due to the expansion of power system and the increase of power plants and so on. Anticipated problems due to the increased short circuit current are as follows:

1) Shortage of breaking capability of circuit breakers

2) Damage to the series of equipments such as transformers, circuit-breakers or disconnecting switches

3) Trouble in communication lines by induced voltage due to the increased fault current

(2) Countermeasures

Countermeasures against the increased short circuit current are shown as follows:

1) System separation

2) Adoption of high impedance equipment

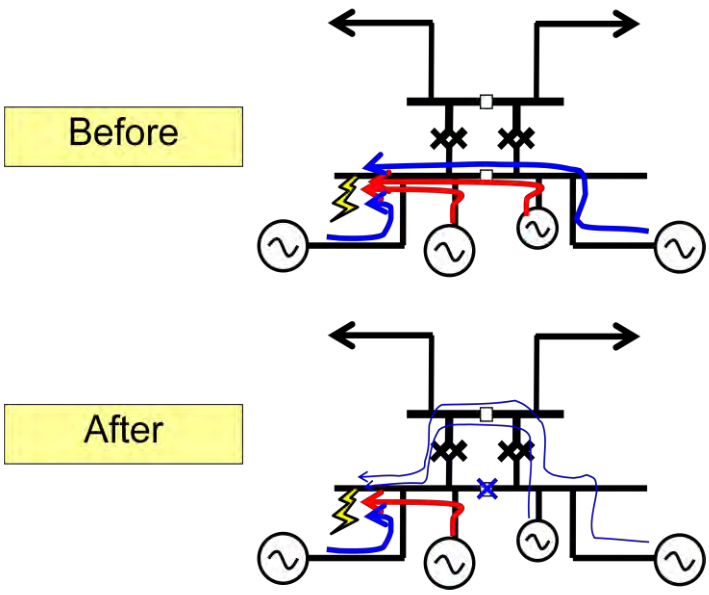
3) Installation of Current Limiting Reactor

4) Adoption of a higher voltage system

5) DC interconnection

6) Replacement of equipment with higher capability

For example, the following figures show the effect of system separation method. The upper and lower figure shows the flow of short-circuit current before and after countermeasure respectively. When the system is separated, the short circuit current becomes smaller because the impedance between generators and fault point becomes larger. System separation is a common method to decrease short circuit current because this can be implemented without any cost. However, it needs to be noted that the measure at the same time decreases the reliability of the power system.



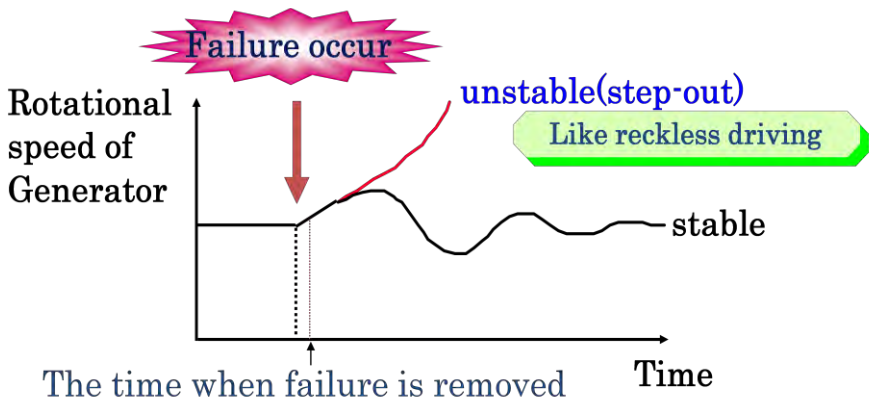
(Source : Study Team)

Figure 3-21 : Effect of system separation

3.2.4 Stability analysis

There are two kinds of stability; one is steady state stability and the other is transient stability. Steady state stability is the degree that electric power can be stably transmitted against rather moderate disturbances during a steady state such as the change of load. Transient stability is the degree that electric power can be stably transmitted against sudden disturbances such as power system failures. Transient stability is mainly checked for power system analysis.

This figure shows the rotational speed of a generator before and after a fault.



(Source : Study Team)

Figure 3-22 : Effect of system separation

When a failure occurs in a power system, generators begin to accelerate. When failure is removed, an accelerated generator may return to steady state with oscillation, showing that the generator is stable. However, after the failure is removed, if the accelerated generator were not able to return to steady state due to the increased speed, then the generator would step-out showing that the generator is unstable. To check transient stability, in other words, to check whether generators are stable or not against disturbances is an important factor of power system analysis.

Countermeasures for instability are roughly divided into three categories,

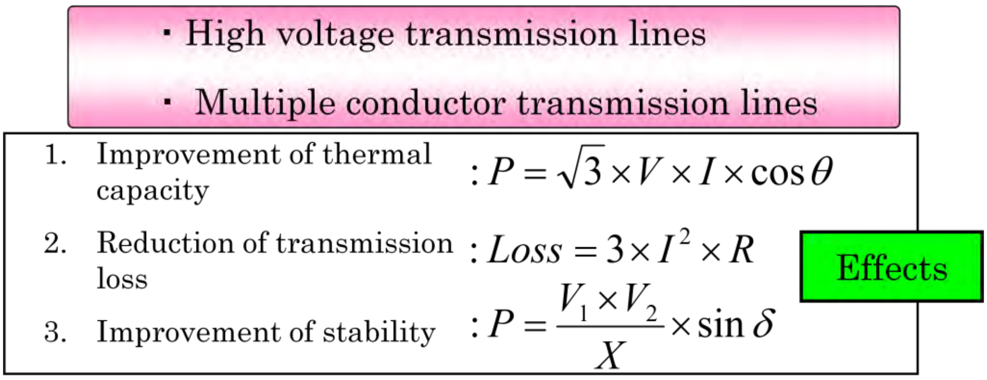
1) Expansion of System
2) Installation of special equipment
3) Installation of relay systems.

Table 3-3 : Countermeasures for instability

Countermeasures	Examples
Power system expansion	Adoption of High Voltage
	Adoption of Multi Conductor
	Installation of Inter-mediate switching station
Installation of special equipment	Installation Series Capacitor
Installation of relay system	Adoption High-Speed Circuit Breaking

(Source : Study Team)

Recently power stations tend to be constructed in remote areas and their scales are getting larger. Therefore, the long distance and large capacity transmission lines are increasingly necessary. As the countermeasures, the application of high voltage transmission lines and multiple conductor transmission lines are considered. By adopting these countermeasures, the following three effects can be expected.



(Source : Study Team)

Figure 3-23 : Effect of high voltage and multiple conductor transmission lines