Sustainable Management of Small Hydropower for Rural Electrification in Lao PDR by Economic Blueprint Perspective

Akhomdeth Vongsay and Xayphone Bounsou

Abstract— *Electric energy generation mostly from hydroelectric power, thermal power, nuclear power and renewable sources is one of the major key factors for economic and social development in the entire developed and developing nation of the world. The Government of Laos (GoL) has declared that the small hydropower (SHP) with the capacity less than 15 MW is Renewable Energy (RE).The main challenges for the Government of Laos is how to manage the SHP for the sustainable ways in order to contribute for the GoL's golden target for household to have electricity for 90% in the year 2020. Currently, the government has already approved 35 projects with the capacity less than 5 Mw for the rural development. In this study the main purpose is to analyze the 12 existing small hydropower projects in Lao PDR (with the capacity less than 5 MW) that was not sustainable then will propose the recommendation the suitable management tools by using the Economic, Social and Ecological blueprint model (ESE model). In this paper will introduce only the concept of the economyblueprint perspectivethat is one of the three perspectives in the ESE model.*

Keywords— **Sustainable, small hydro project (SHP), government of Lao PDR (GoL), economic, social and ecological blueprint model (ESE model).**

1. INTRODUCTION

Electric power system of Lao PDR is separated into three parts by regions (Northern, Central regions and Southern) because there is no national grid connected from north to south the extensions of electric power grids to remote households are either prohibitively expensive or economically unjustified.

A recent World Bank study estimates that more than 1.8 billion rural people or two thirds of total rural population in developing countries still have not attained any grid-based electricity services [1].

In many Asian and African countries such as Bangladesh, Botswana, Ethiopia, Kenya and Yemen, less than 5 percent of rural villagers have access to grid services [2].

Rural electrification is often the preferred program for promoting equity and development in poor countries. Several reasons account for this. First, electricity is perceived as a modern source of energy, essential to development. In most parts of the world, areas without electricity are far less developed than those with access.

The Government plans to expand electrification in remote areas through two methods. One is to expand the grid to comparatively easily accessible areas. The other is to provide off-grid supplies to remote areas where it is difficult to expand the present grid due to environment or cost reasons [3].

In rural areas, electricity serves many purposes. It can improve business and farm productivity, ease the burden of household tasks, and provide more efficient lighting for rural families. Increased accessibility to electricity in rural areas will improve living standards and help reduce poverty [4]. At present more than 20,000 households have been connected to solar home systems and SHP have been providing electricity to people living in rural and remote area [5]. According to Government's strategy is to raise the national electrification rate to an ambitious target of 90% by the year 2020 [Appendix 1].Development of off-grid renewable energy sources such as SHP, solar, wind, biomass; increasing energy self-sufficiency and security; and implementation of power projects for maximum long-term sustainability including managing in sustainable ways for renewable energy sources.

In many years ago, electric power generation has been expended from 33 MW in 1975 (independent) to3,205 MW in 2012 as 99.8% from hydropower generation, 0.07% (1.51MW) from diesel generator and 0.02% (0.47MW) from Solar power and others. Currently the electrification ratio is approximately 82.25% (Appendix 1,3) and will be 90% in 2020 if the entire SHP plan are implemented and the existing plan are still running in full capacity (80% by grid plus 10% by off-grid) [6]. Therefore, the SHP will contribute for the off-grid supplies to remote areas where it is difficult to expand the present On-grid due to environment or cost reasons.

2. STATE OF PROBLEM

Most of the research agrees that the small hydro electric energy generation is environment friendly and it's very useful of generating the electricity in rural and urban area. The use of renewable sources is the most valuable solutions to reduce the environmental problems associated with fossil fuels based electric energy generation and achieve clean and sustainable energy development [7].

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The electric power sector is the government main development priorities in order to contribute for the rural electrification of 90% by the year 2020 nationwide (70% by 2010, 80% by 2015). Therefore, for reaching the target, government of Lao PDR is currently promoting the development of hydropower resources especially the Small hydro power for rural electrification.

But the main problems from rural electrification are: high initial investment with the rate of return, no actual tools for management and technical inspection standards. Currently, small hydropower development that provincial is responsible were not sustainable due to natural disaster, lack of management and lack of technical and budget for maintenance.

In term of SHP development, there are 5 stages to be considering such as: Preliminary survey, Basic plan survey, Implementation plan, Construction, O&M and Administration. In This research is to focus all stages by using the ESE model and try toimprove the project management to meet the target of sustainable development of Small Hydropower management in Lao PDR.

Fig.1. The 5 stages for small hydropower development

3. RESEARCH OBJECTIVES

The main purpose of research is to investigate the good management tools for small hydropower in rural area for the sustainable development also to improve the standard of living. This study is using the Economic, Social and Ecologicalblueprint model (ESE model) to identify the factors and creating methodology for trying to solve the problems in case of existing small hydropower that located from northern to southern of Lao PDR (Appendix 4)that provincial is responsible such as:

- To review concept of small hydropower development related to policy and strategy of GOL.
- To investigate of the small hydropower management methodology to take into account the new situation of development in rural area.
- To identify methodology with the suitable method of SHP management for rural electrification.

4. METHODOLOGY

In this study the main purpose is to analyze the 12 existing small hydropower projects in Lao PDR (with the capacity less than 5 MW) that was not sustainable. In thispaper willbeintroduced only the concept of the economyblueprint perspective that is one of the three perspectives in the ESE model for the sustainable small hydropower management in Lao PDR.

The method are separate into 2 procedures; first is the data collection and analysis of the 12 existing small hydropower projects in Lao PDR (with the capacity less than 5 MW, Appendix 2) that aren't sustainable by using the modified format fromMinistry of Energy and Mines, Lao PDR and ASEAN Energy Centre. Secondly, recommendation of the suitable management tools for sustainable and effectiveness management of small hydropower in rural area of Lao PDR by using the Economic, Social and Ecologicalblueprint model (ESE model).

In this paper will be introduced only the concept of the economyblueprint perspective that is one of the three perspectives in the ESE model for the sustainable small hydropower management in Lao PDR.

4.1 Data Collection and Analysis Method

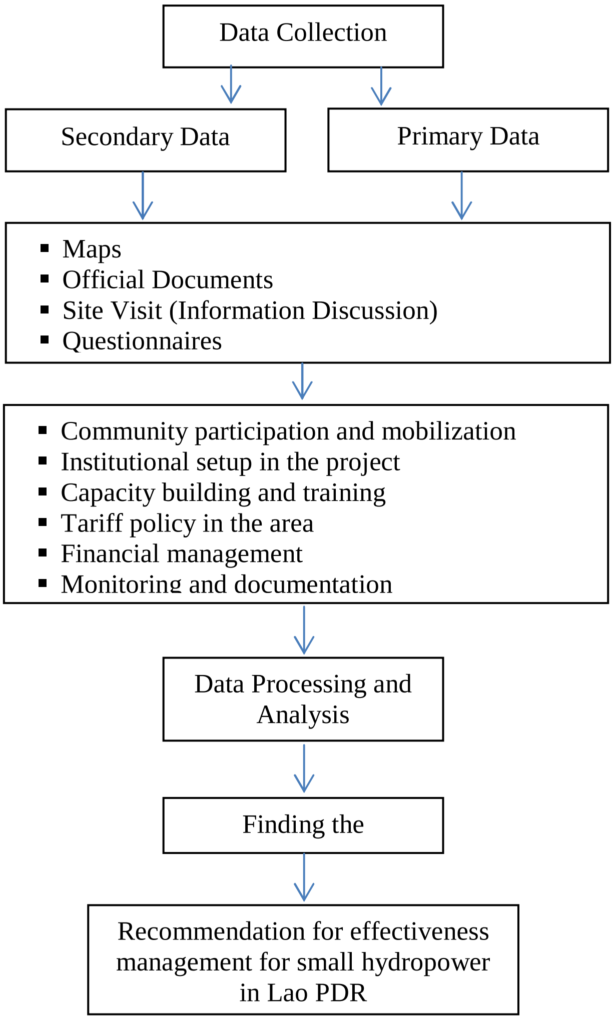

Fig. 2. Data collection and analysis method

4.1.1 Outcome of the data analysis

After using the modified format from Department of Policy and Planning, Ministry of Energy and Mines, Lao PDR and ASEAN Energy Centre to the existing 12 sample projects in to this study, we can identifies as the following:

- From the initial phase the participation from the community are very limited.
- Unclear of the responsibility between the local and central government.
- The over/less estimation of the project power generation.
- The unclear of the tariff policy.
- The low quality of the project's electric equipment
- Income can't cover the operation and maintenance
- Drop of power supply in dry season can not meet the power demand
- Lack of financial management mechanism.
- Lack of technical skill and educated staffs, because qualified staff is crucial for a sustainable operation of the plant.

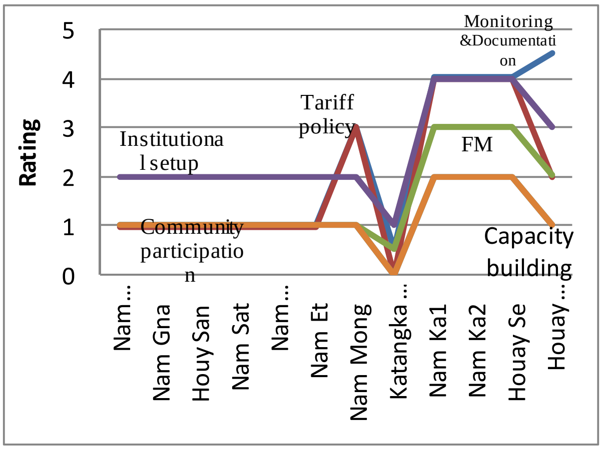

Fig. 3. The outcome of the 12 projects analysis

As shown in the graph that all 12 project have difficulty on the community participation and capacity building for the staff in the project. The projects that have more score on the questionnaire are Nam Mong, Nam Ka1&2 and Houay Se due to these projects is already connected to the EDL's grid. Therefore, the monitoring, tariff policy, institutional setup and financial management are already in place.

In conclusion, the project that responsible by PDEM are clearly having problem in mentioned areas as indicated in the analysis graph.

4.2 ESE model procedures

In general the Sustainable development of the hydropower sector is founded on 3 important principles namely:

- Economic sustainability relies upon the maintenance of the renewable resource base, and the use of non-renewable resource rents to support the development of other factor of production;
- Social sustainability is based upon the principles of inclusiveness, mutual understanding and consensus; and
- Ecological sustainability relies upon the avoidance of irreversible environmental impacts such as the loss of biodiversity, accumulation of persistent pollutants, or disruption of ecological cycles [17]

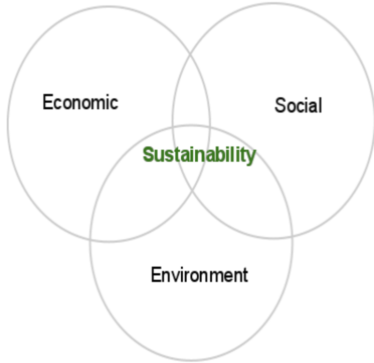

Fig. 4. The relationship of ESE

4.2.1 Economic Blueprint

4.2.1.1 General technical aspect

To create electricity in a small hydro power station the flow and head are the most important parameters for the design of a hydro power plant and following question are essential:

- How much water is available throughout the year for the turbine (flow)?
- What is the possible difference in height (head)?

Also the information which must be available is the general location and topography of the site and the distance to the potential electricity consumers and/or the closest power line near by.

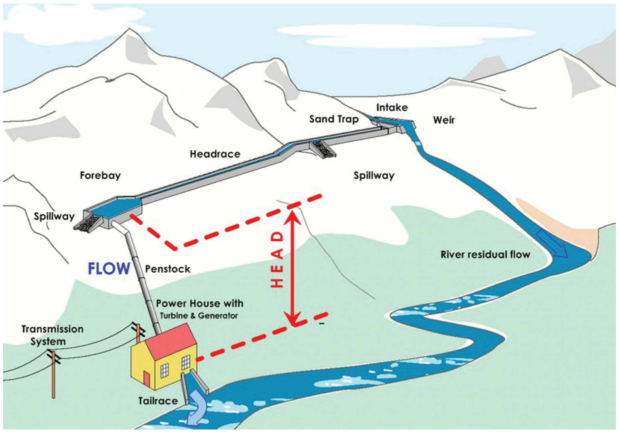

Fig. 5. Typical example of a diversion type run of river hydropower plant

4.2.1.2 Measure and Collect river flow and head data

The flow measurement has to be taken everyday during one full year. Depending on the size of the river there are different methods to measure such as bucket method, float method, current meter method (velocity-area-methods), sharp crested weir method and salt concentration method

For hydropower design it is very important to have flow data over as many year as possible to be sure how much water (in rainy and dry season) is available to run a turbine. These data give the designer the basic information for the select of a turbine that works efficiently.

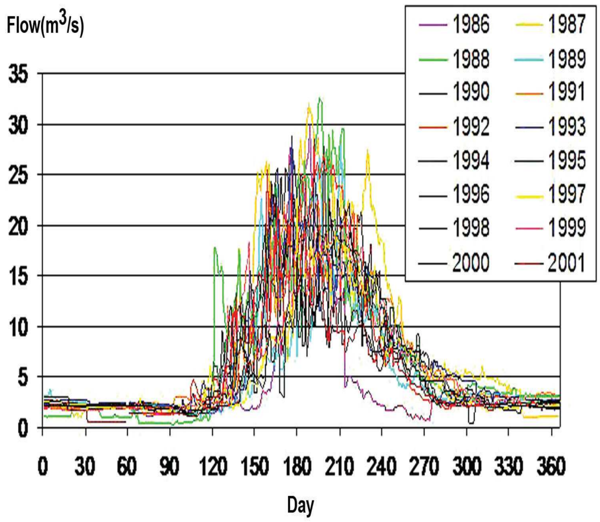

Fig. 6. Example of hydrographs for a 16 period

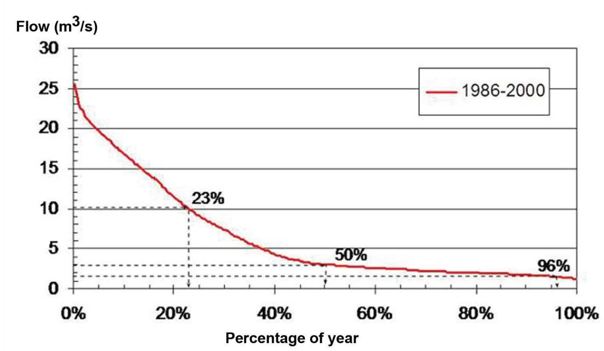

Fig. 7. Flow duration curve

The flow duration curve is generated by sorting all measured flow data size wise and printing them over 100% of the time covered by the measurements. The graph shown that during 23% of the time the discharge is high than 10 m3/s. this curve is the most important information for the design of the hydropower plant.

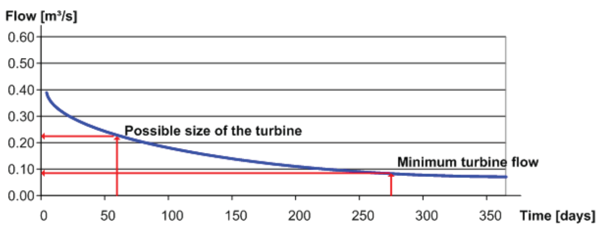

Fig. 8. Example of a flow duration curve for one year

The flow duration curve is generated from the river discharge curve by sorting all the 365 values. Based on the flow duration curve, the designer evaluates the available capacity.

Also, the Flood peak water level (height) should be estimated at the proposed powerhouse location. Thus, the site shall be selected with full confidence that frequent flooding (submergence) of powerhouse would not occur. Creager's flood curve method as described below. This method might be applicable to estimate design floods in the regional areas where no flood data is available.

The Creager's equation is given by the following formula:

$$Q_q = 46 \times C \times A^{a-1} \quad (1)$$

$$a = 0.894 \times A^{-0.048} \quad (2)$$

where

Q_q: Specific peak discharge (cubic ft/sec/square mile)

C: Creager's coefficient (40 for 100 yrs, 30 for 50 yrs)

A: Catchment area (square mile)

The unit conversions for feet and mile are as follows:

1 ft^3 = 0.02832 m^3

1 km^2 = 0.3861 $mile^2$

Head measurement is the difference in height between the water level of the planned forebay and the planned position of the turbine shaft there are different methods to measure such as water level, pressure gauge, barometer/altimeter, clinometer and level instrument.

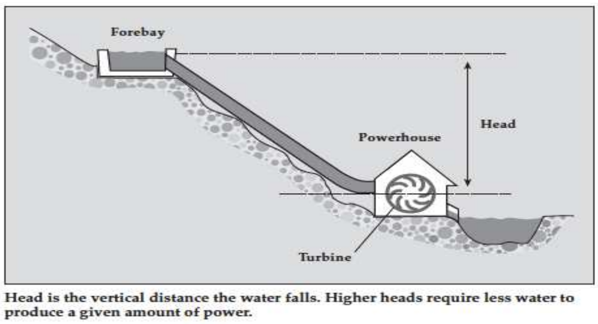

Fig. 9. General layout of Small Hydropower project

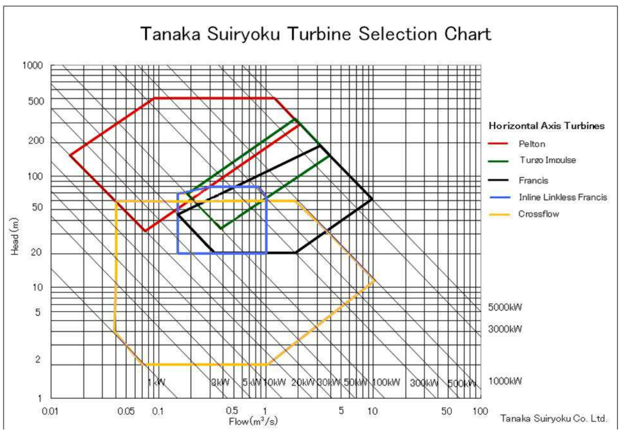

Fig. 10. Tanaka Suiryoku turbine selection chart

Table 1. Example of total expenditure

Target Village	X	Y	Z	Average
Firewood	10	12	14	12
Kerosene/Diesel Lump	12	12	12	12
Candle	14	14	16	14.7
Dry cell Battery	10	12	12	11.3
Private Diesel Genset	20	0	14	11.3
Electricity Tariff	0	0	0	0
Others	10	14	12	12
Total Energy Expense	**76**	**64**	**80**	**73.42**
Total Expenditure	**760**	**800**	**800**	**786.66**
% of EnergyExpense	10%	8%	10%	9.3%

4.2.1.3 Calculation of possible hydro electrical power

As mention the minimum flow and head are the most important information, when is known the theoretical hydro power is calculate as the following:

$$P[W] = Q[m3/s] \times H[m] \times 9.81 \quad (3)$$

where

P = Power in Watt

Q = Minimum available flow

H = Head, difference in height in meter

This formula shows the hydraulic capacity only and refers to 100% efficiency without losses. Losses in penstock, turbine, gear transmission, generator and electricity transmission reduce the final electrical power. By calculating losses of 20-30%, the final electrical power will approximately be:

$$P[W] = Q[m3/s] \times H[m] \times 7 \quad (4)$$

4.2.2 Energy Tariff Policy

Goods and services purchased make up household expenditure, while household consumption is defined as household expenditure plus the value of own produced goods taken out from households' own production. The difference in two concepts is basically caused by own produced rice and other crops, and meat/egg of own domesticated Livestock.

Consumption is importantto know living standard of household, and is utilized for judging poor and non-poor household in Laos. The target village should have the survey on the total expenditure such as food, education, medical, transport, energy because is important data to know capability of household for paying electricity tariff.

4.2.2.1 Ability To Pay (ATP) for electricity

Firstly we should calculate thetotal expenditure of the target villages than fine out the percentage of energy expenditure among the total expenditure.

For Example: The target villages are X, Y, Z and the total average expenditure is 786.66 and the percentage of average energy expense is 9.3%

According to the “Lao PDR Institutional Development for Off-grid Electrification”,the off-grid householdswere spendingabout l0% of their income on electricity and other lightingsources. The EDL Tariff Studyof SPRE II, also mentioned that electricity price should not exceedabout 10%of the householdincome.Judging from these conditions, ability to pay for electricity is assumed to be 5% - 10% ofhouseholdexpenditure.

4.2.2.2 Willingness To Pay (WTP) for Electricity

Contingent Valuation Method (CVM) is a method of estimating the value that a person placed on a good. The approach asks people to directly report their WTP to obtain a specified good, rather than inferring them from observed behaviors in regular market places.

In general there are 2 payments for accessing to electricity such as connection fee and monthly electricity tariff that depends on kWh.

Setting the Bid Prices (BP)

The bid prices used for the Survey in the target villages including the poor and non-poor strata were prepared base on pre-test of interview survey, price of alternative energy sources, and existing electricity tariff. The connection free and electricity tariff should agreed by 80% of households in the target villages.

The BP for the connection fee shouldn’t exceed the connection fees by the ADB’s Northern Area Rural Power Distribution Project in Lao PDR which is US$65.

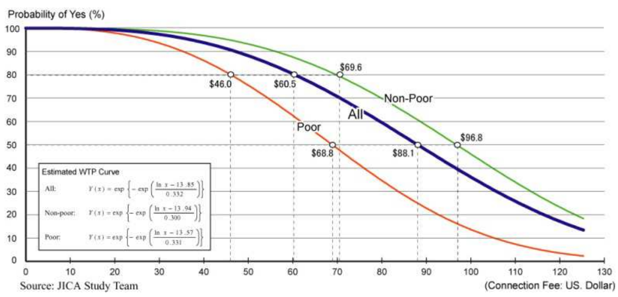

Fig. 11. Setting the willingness to pay tariff

The BP for the Electricity Tariff should compare to the Electricity Du Lao (EDL)’s residential consumer category tariff (US¢ 1.1 for 0- 50 kWh/month, US¢ 2.6 for 51- 150 kWh/month, and US¢ 7.4 for above 150 kWh/month) and also should compare with the existing electricity tariff of isolated diesel generator gird.

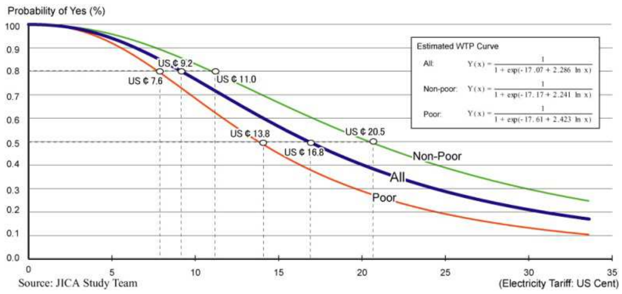

Fig. 12. Setting the connection fee

As show in the graph the connection fee and electricity tariff is the value at the intersection of the WTP curve and vertical line of 80% indicate that 80% of household have willingness to pay against the bid price [9].

4.2.3 Subsidy System for Hydropower

Financial assistance to the hydropower plant construction cost.

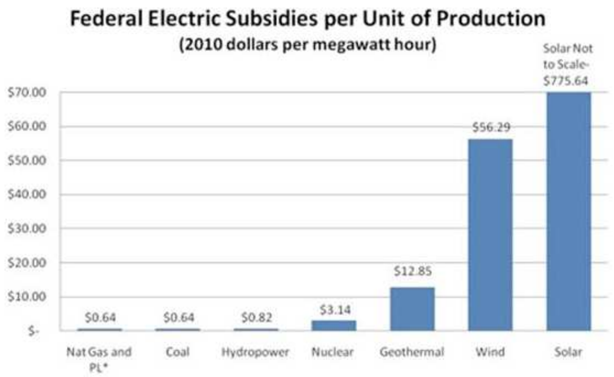

Fig. 13. Electricsubsidiesperunitofpreduction *[8]*

For example: in Japan the subsidy system are:

Table 2. Example of subsidies system in Japan

Scale	*Subsidy rate*
5MW-30MW	within 1/10
1MW-5MW	within 2/10
-1MW (Local government)	within ½
-1MW (Others)	within 1/3

4.2.4 Feed-In Tariff (FIT)

Model structure is that in each scenario calculates the electricity production and total costs of CSP plants and HVDC transmission installations on a yearly basis. Final outputs are total investment costs, total electricity to grid, and average annual levelized electricity costs, used to calculate feed-in tariff rates.

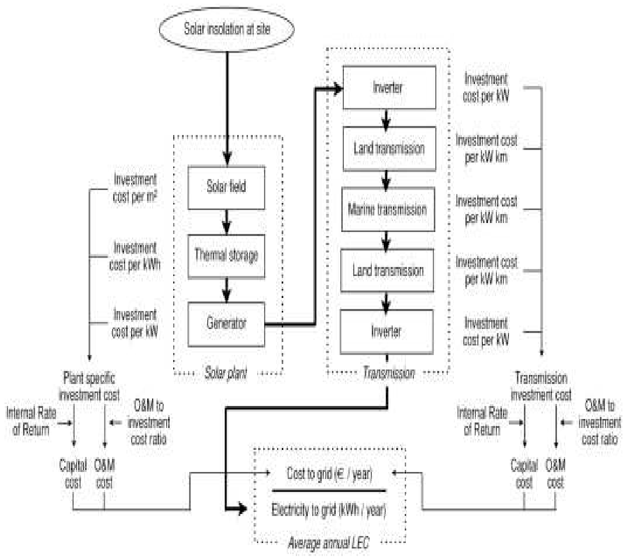

Fig. 14. FeedintariffstructureforSolarsystem *[10]*

The Japanese experiences for the new scheme of Feed-in Tariffs for renewable energy electricity since July 2012.

Table 3. Example of feed in tariff in Japan case

Feed-in tariffs applicable on 1st July 2012 in Japan		
Sector	Duration (years)	Tariff (c€/kWh)
Wind	20	
<20 kW		55,9
>20 kW		22,3
Geothermal	15	
<15 MW		40,6
>15 MW		26,4
Hydro	20	
<200 kW		34,5
200kW<P<1 MW		29,5
1MW< P <30MW		24,4
PV		
<10 kW for generated surplus	10	40,6
>10 kW	20	40,6
Biogas from sewage sludge and non fossil animal matter	20	39,6
Combustion of non fossile animal or plant matter	20	
Sewage sludge and municipal waste		17,3
Waste from cut wood		32,5
Hardwood		24,4
Construction waste		13,2

Source: METI

5. CONCLUSIONS

This paper study is using only the Economic blueprint perspective from the ESE model (Economic, Social and Ecologicalto solve the problems in the case of the existing small hydropower that located from northern to southern of Lao PDR.

Also this study will contribute to the new small hydropower in the future in term of sustainable management from the economic perspective.

As we have been discussed that the first component to focus on is the general technical aspect such as measure, collect river flow (flow duration curve)and head data is the must component for the planner to do in order to calculate the final electrical powerwith the losses of 20-30% (P[W] = Q[m3/s] x H[m] x 9.81), also the planner need to consider of the selected site with full confidence that frequent flooding (submergence) of powerhouse would not occur by using the Creager's method ($Q_q = 46 \times C \times A^{a-1}$) because over estimated of electrical power and damaging the powerhouse by flooded is one of the main problem for the small hydropower in Lao PDR.

The second component is energy tariff policy because for the project to cover the operation and maintaining cost the income form the electricity charges is the most important, and the tariff policy should include the setting up the ability to pay (ATP) for electricity and the study shown that the ability to pay for electricity is assumed to be 5%-10% of household expenditure. For the willingness to pay (WTP) for Electricity, in general there are 2 payments for accessing to electricity such as connection fee and monthly electricity tariff that depends on kWh and the detail is already discussed in the section 4.2.2.2. In addition, all tariff should agreed by 80% of households in the target villages.

The other component is also very important for the government to consider because from the analysis of the 12 existing small hydropower in Lao PDR shown that there are not any concrete incentive support from the government. Therefore, the subsidy system and feed in tariff is also an option for government to be considered.

Again this paper is using only economic blueprint perspective for the research and of cause there will be other 2 blueprints perspective namely; Social and Ecological to be study and combine it together for the sustainable management of small hydropower in Lao PDR.

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APPENDIXS

Table A1. The Forecast ratio of electrify up to 2020

No	Plants Name	Province Location	Install capacity (kW)	Commercial Operation Date
1	Nam Boun 1	Phongsaly	110.0	1996
2	Nam Gna	Phongsaly	110.0	2010
3	Houy San	Huaphanh	110.0	1995
4	Nam Sat	Huaphanh	250.0	1999
5	Nam Phoune	Huaphanh	60	1995
6	Nam Et	Huaphanh	60	1995
7	Nam Mong	Luang Prabang	70	1996
8	Katang Kadeuang	Luang Prabang	3	N.A
9	Nam Ka1	Xieng Khuang	24	1999
10	Nam Ka2	Xieng Khuang	75	2002
11	Houay Se	Oudomxay	80	2003
12	Houay Samong	Attapeu	113.0	2003
Total			1,065.0	

Table A2. List of Existing SHP that responsible by Provincial

Description/Year	2005	2012	2020
Households	874,476	1,066,017	1,231,454
Households to be electrifies	508,799	189,255	1,108,309
In Percentage	58.2%	82.25%	90%
Population	5,900,000	6,256,197	7,261,600

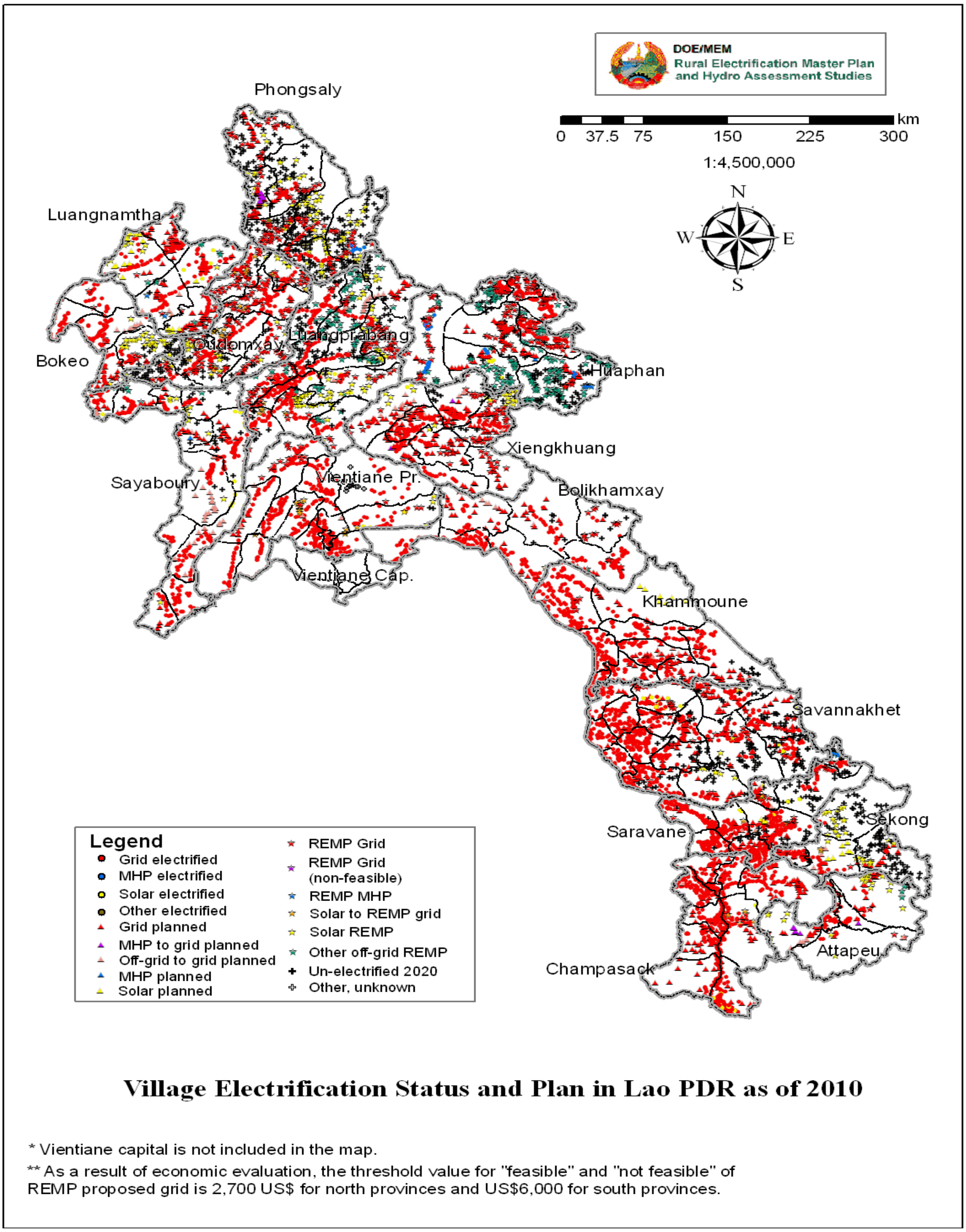

Fig. A1. Map of Village Electrification Status and Plan in Lao PDR

Fig. A2. 12 existing small hydropower project with the capacity less than 5 Mw in Lao PDR