CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, results of research are discussed based on site survey, interviews with end-users and economic calculation that were being made during this research work.

4.1 Empirical results of the Photovoltaic system's survey

4.1.1 Renewable Energy for Sustainable Development

To enhance the sustainability of electricity supply by photovoltaic systems, the two following aspects should be considered:

1) Suitability of renewable energy provided to community

- Villagers should be familiar with the selected technology.
- Villagers should have some experiences on this selected technology and know accurately how to operate with it.
- Villagers have an acceptance on this selected technology.
- Villagers should be able to conduct the system maintenance by themselves.
- There should spare parts and skilled technician taking in charge of equipment when equipment fails or damaged.

2) Readiness and acceptance of villager on the related changes

In order to make any renewable system sustainable and long serving to the villagers or community, following points should be satisfied first:

- Villagers desire of electricity supply and satisfy with the selected technology.
- Willingness to pay for the maintenance fee of electrical equipment Within their house.
- Willingness to pay for system maintenance fee.
- Willingness to co-invest on the necessary equipment.

Besides considering from the two above-mentioned aspects, it is necessary to establish an organization responsible for evaluating the system design, installation, operation and monitoring in order to improve the sustainability of photovoltaic system.

4.1.2 Advantage and Disadvantage of Various Photovoltaic Systems

Each technology has advantages and disadvantages to the user, the installer and system performance. Followings are the listings of the principal advantages and disadvantages associated with following three different systems analyzed for rural electrifications options:

- Centralized Diesel System
- Centralized Solar System
- Individual Solar Home System

1) Centralized Diesel System

Advantages	Disadvantages
- Lowest initial system cost. - Rapid speed in responding fluctuations in the loads. - Takes short time to start and supply to system. - Rapid, simple shut down process. - Moderate in bulk and weight.	- Fuel requires use of foreign exchange. - Generally, fuel expensive, not easily available as it is dependent on shipping and foreign supplier. - Storing fuel can be bulky depending upon the remoteness of the location and can be also risky. - Replacement parts are not easily available and people may not have much knowledge of the parts. - Higher level of operator's training is required as there are too many mechanically moving parts. - Foreign political situation controls over fuel prices. - Noise, noxious smoke emission which is unhealthy and having bad smell. - Fossil fuel is toxic and may damage land and sea environment in case of spill out. - Short useful life of machinery. - Functions inefficiently and with higher maintenance requirements at lighter loads.

Advantages	Disadvantages
	- Relatively high training and maintenance cost. - A skilled operator is required to operator the complex mechanical system.

2) Centralized Solar System

Advantages	Disadvantages
- No fossil fuel requires. - Instantaneous response to load changes with excellent voltage and frequency regulation, in case the system is oversized than the load profile of the remote areas. - Unattended operation. - No moving mechanical components. - Less environmental impacts. - System is more reliable as long as system is designed based upon the load profile community.	- High capital requirement. - Highly trained electronic technician required for maintenance. - Spare parts are not easily available. - Limited system experience rather than monitored demonstration projects. - Requires a large, shade free area. - Power supply capacity is weather dependent.

3) Individual Solar Home System

Advantages	Disadvantages
- Simple proven designs are available. - Less service required and easily serviceable when required. - Components are modular and few in numbers. - Less training is needed for installer and field maintenance. - System size is modular and can be modified according to load demand. - Moderate capital cost (high component cost but no grid extension cost). - Readily available spare parts. - Individually dependent system rather than centralized system. - It is modular and easily modifiable to accommodate changes in load requirement. - Rapid installation possible. - Very less environmental impact. - No noise or harmful smoke emission. - Little change in efficiency with the fluctuations of load. - Simple design and maintenance can be done locally. - No fossil fuel required.	- Power availability somewhat dependent on the weather. - Requires shade free mounting location. - Requires more customer attention and training than other systems.

Analyzing the advantages and disadvantages of each of available technologies to electrify the rural communities, we can rank the appropriate generation technologies as:

INDIVIDUAL SYSTEMS

- Only solar photovoltaic home system should be considered as it is solely dependent on individual users how they use the system and doesn't affect in the performance of the system by the another end user unlike in case of centralized system.

CENTRALISED SYSTEMS

- Centralized solar systems should be considered where the system is competitive in cost with micro-hydro, or diesel or small biomass system.

The first consideration for new rural electrification should be the extension of an existing grid. Generally reliability, power capacity and lower operating cost of grid supply make it the lowest cost option compared to all other rural electricity supply options. Initial capital cost, however, may be too high to be justified and individual or community electrical supply systems necessary.

Where the grid extension is too costly and stand-alone system must be installed, the primary choice is between central power and individual solar power. Where the load is almost exclusively domestic, individual power systems are clearly technically and socially superior to any central system. Individual systems are usually also financially superior unless the houses are very close together, a community grid already exists or a grid extension to that community can reasonably be expected to occur within five years of the initial installation.

Where a significant industrial or commercial load exists within the community, the decision to interconnect all consumers with a central power source or to keep the commercial and the domestic loads separate must be made on the basis of (1) the type of commercial load (2) the timing of the commercial and the domestic load peaks, and (3) the relative scale of the commercial and the domestic loads.

4.2 Evaluation of Impacts of Photovoltaic Rural Electrification Systems in Thailand

Rural electrification has effects on economy, society, knowledge, etc., of people in the villages or households where it is introduced. But, many researchers and experts have observed that the economic benefits of rural electrification are not as great as the social benefits. Additionally, in some cases, the benefits of electricity do not outweigh the expense of the electricity.

Two positive economic effects of rural electrification are: 1) electricity can power machines that make the labor of farmers and small-scale manufacturers easier and more efficient and, 2) lighting that lasts longer in the evening can extend longer opening of stores and increase sales for small shops in the village as well as the longer economic activities in the each households. These changes may give the village's economy a small boost. The electricity is just one of the many necessary factors for an economic development initiative to be successful. In places where many of these variables are not present, electricity will not spur an economic boom. Yet, in areas where many or all of the elements of successful economic development are present and with the lack of electricity being the limiting factor, the introduction of electricity will certainly benefit the local economy.

Another important economic aspect to be considered is whether or not the rural community that is receiving electricity has the cash flow available to fund an electrification project. In most rural villages, there is a very limited amount of cash available and there are few, if any, sources of cash coming into the community. Rural electrification can be in a drain if the village has already limited cash supply because the village is paying outside of the community for the use of electricity or for the equipment to generate their own. Thus a rural electrification project will have a negative economic impact on the community unless the community has adequate cash on hand and cash flowing in as well as out.

The impact of electrification on the rural economy is a mix of positive and negative effects. The most successful introduction happens in a community where there is already sufficient economic development in place to support the costs of electrification and to fully take advantage of the opportunities that electricity can provide.

4.2.1 Social Impacts

The Thai Government's 9th National Economic and Social Development Plan (NESDP) has emphasized the promotions of local and community participation to improve the management mechanism of natural resources and the environment at the community level, so as to achieve social approval of energy security. Once the rural community has secured a reliable electricity supply, they can have access to modern communication media like TV and radios, which can play a vital role in creating a knowledge-based society. Improved electricity supply also generates extra economic activities in the community, improving the capacity-building of the poor. Overall extra economic activities in each house-hold in the community increase the capital development of community as a whole. Due to improvement in lighting and information dissemination, there would be improvement in community health. With reliable electricity supply in the community, all modern gadgets will be operational in the community, increasing extra creativity and fostering community's well-being.

4.2.2 Modern media

PV systems such as off-grid or individual solar home system are playing major role in electrifying the remote communities. There is no doubt that once people have an access to electricity, they will have access to modern mass media communication. Because of the clean light they are having due to solar energy will also give them more time to spend in economic, social, educational activities even at late night. Without electricity villages would be silent by it gets dark. By using electricity, the massive reduction in dry cell battery can be seen, unless otherwise villager will be using for their transistor radios and which possesses environmental threat as rural communities doesn't have much of knowledge about battery disposal in their communities. Government has many TV and Radio programmes transmitted targeting the rural communities for their economic development at grass-root level. For the places where central grid cannot expect reach with 5 or 10 years of time due to remoteness and scattered settlement of the communities and uneconomic grid extension cost, so only possible solution remaining is to utilize PV systems like micro or mini-grid or solar home system to provide electricity in competitive cost. PV powered school also can teach computer education and give to internet access in remote schools of the country, letting the pupils to access the vast information sources of the modern cyber network. In remote school such facilities must be installed soonest possible otherwise there will be gap oh knowledge between pupils from remote and urban schools. Table 19 below shows the number of computer and internet users in Thailand.

Table 19 Computer and Internet Users in Thailand, 2004

(Unit: In thousand)

Region	To use computer	To use internet
Whole Kingdom	12,542.80	6,971.50
Municipal	6,438.60	4,155.70
Non-municipal	6,104.20	2,815.80

Source: Statistical Year Book Thailand 2004.

As indicated by table, the most of the internet and computer users are in municipal area. And lesser users are in non municipal areas. The rural places where there is no electricity, the people are deprived of such and electronic mass media communication system, hence increasing the knowledge gap among urban and rural communities. To make a country a well develop in terms of economy and social status, living standard, the government must try to fill this knowledge gap, and make rural community self sufficient in economy wise at grass root level.

Based on sample survey interviewed with 57 respondents, it showed that 91% of respondent revealed that they watch television for entertainment and other useful news and information. They survey also showed that 68% children of total interviewed respondents watch television for entertainment. Figure 10 illustrates the number of watching television for their entertainment and other useful information.

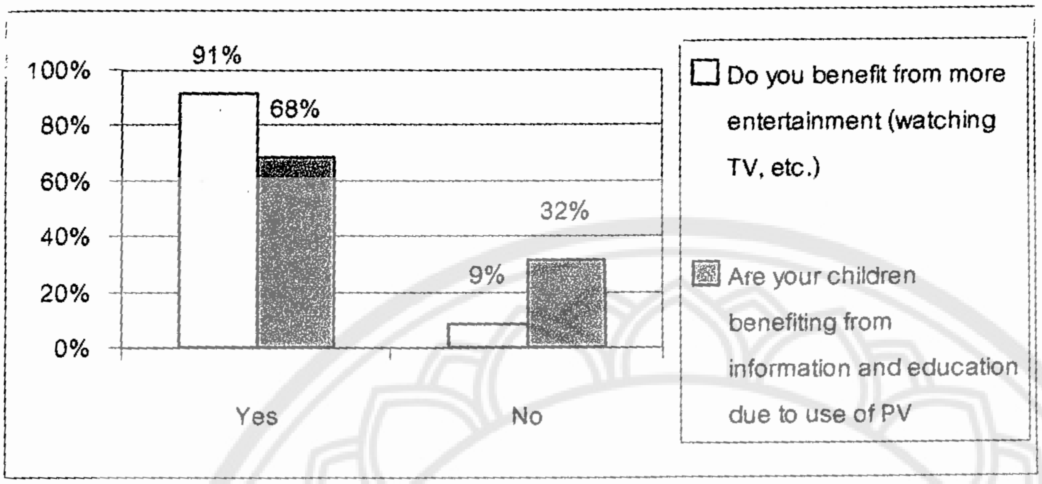

Figure 10 Number of People watching television for their entertainment and other information

The survey also showed that only 5% of the total 57 respondent viewed very satisfied, 40% satisfied, 32% accepted, 21% not satisfied and 2% do not care with the quality of electricity supplied by SHS as illustrated in Figure 11.

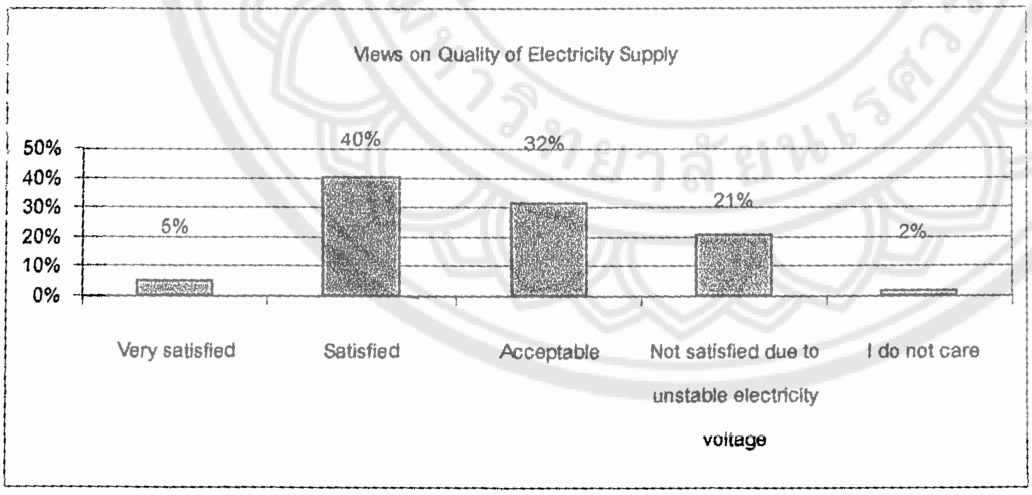

Figure 11 Respondents views on quality of electricity supply by SHS.

When asked, which kind of electricity supply do they prefer? Ninety percent of respondents preferred grid electricity. While 8% preferred PV power and rest 2% diesel/Petrol generator system as illustrated in figure 12 below:

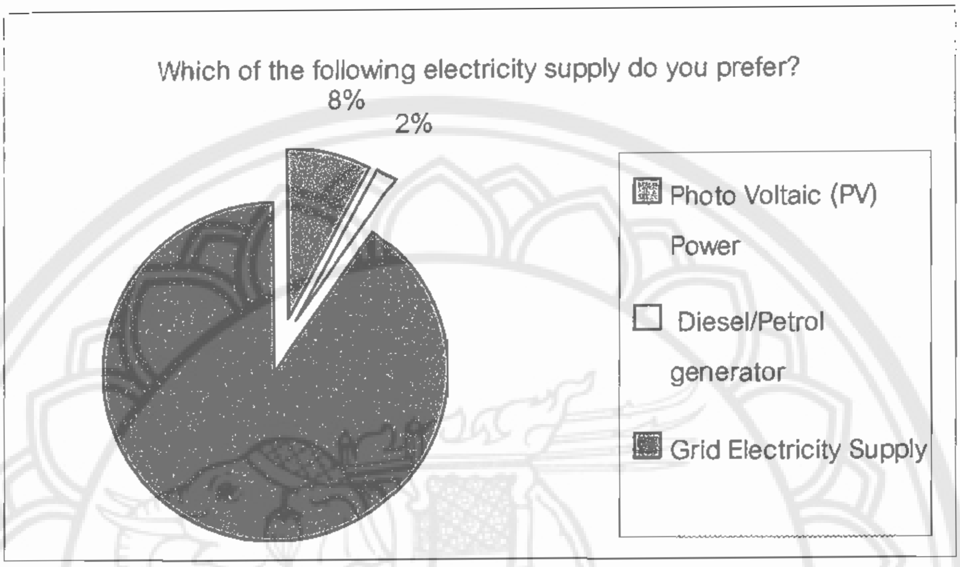

Figure 12 Preferred Electricity Supply System in Rural Thailand.

4.2.3 Attitude

It's human attitude or nature to wish or expect for a better and improved life-style. Same thing implies for rural communities. The community's growing needs and wants will never stops. In such a case, the community's attitude towards solar or other rural electricity supply system might change once the system fails to supply sufficient power to the community. Good knowledge about the system that is being installed in the community must be given to the people in the community. It is necessary to let them know the benefits and limitations of the system and make them interested in it for longer life the system. Without the interest and willingness of the community, any community electricity system may fail in short term. In figure 13, it is illustrated the number of respondents view on different benefits from PV systems.

4.2.4 Impact on Economy

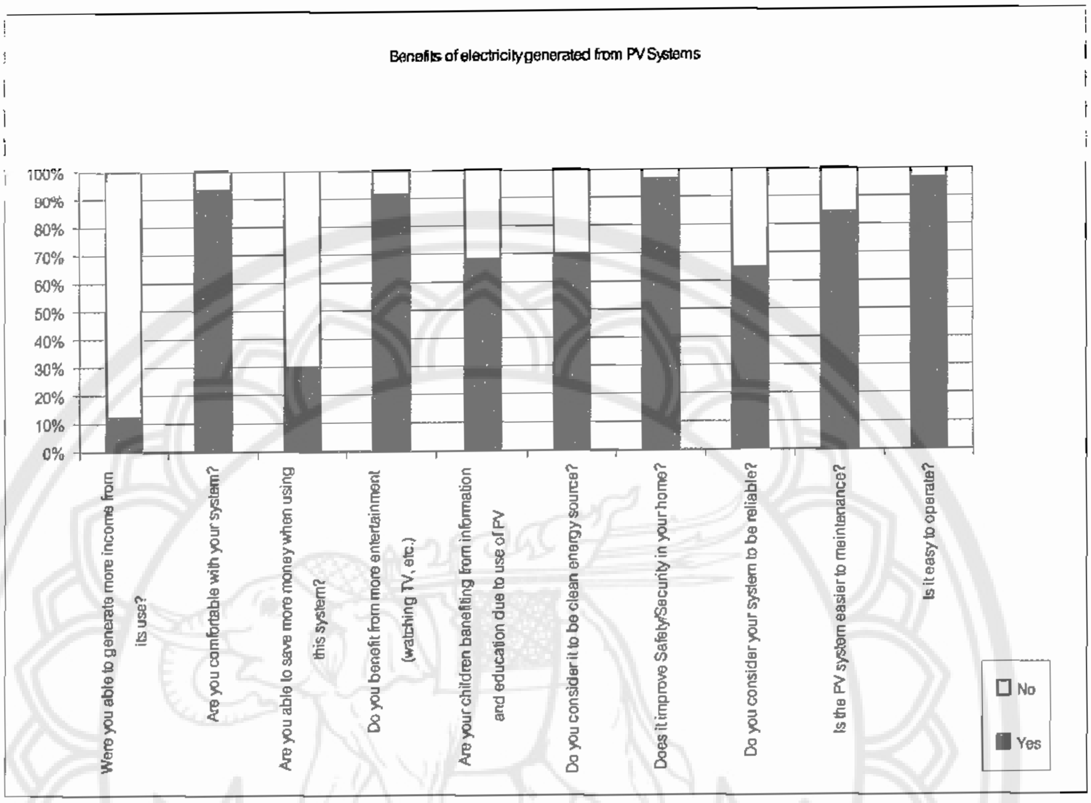

Figure 13 Benefit of Electricity Generated from PV Systems.

For different questions people tend to have different answer and opinion depending upon personal attitude. As mentioned above, 57 persons were sample interviewed and different people have different opinion for the same query asked by the author.

When asked, how you would like to pay for alternative energy source (PV), 57% of the respondent didn't response. This might be because the systems they are using are all free of charge. Twenty three percent (23%) and 9% of respondents were willing to pay in 2 and installments respectively. Nine percent of respondents willing to pay by lump sum method, while 2 percent willing to pay by leas purchase method as illustrated in figure 14.

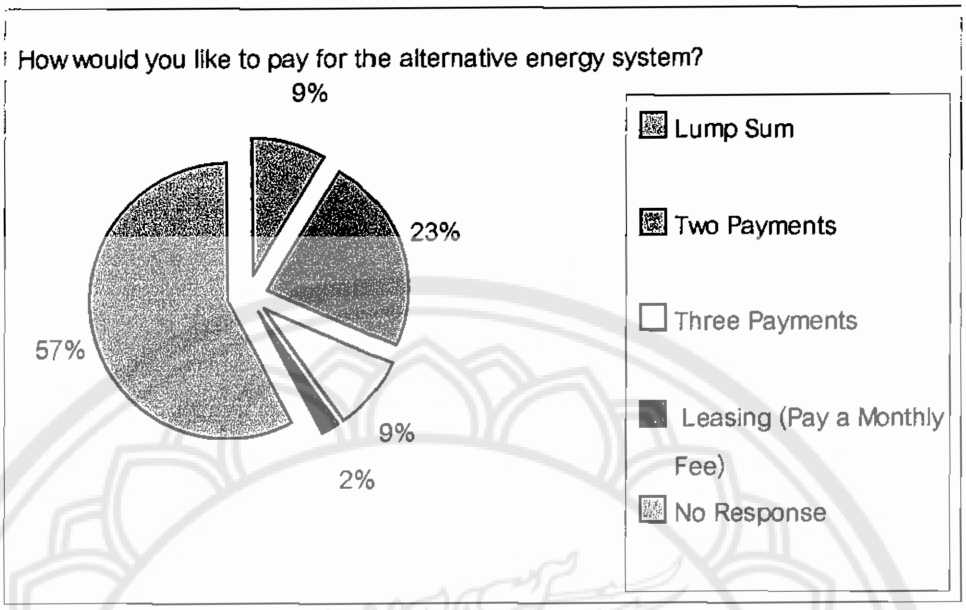

Figure 14 Percentage of respondents willing to pay with different payment method for alternative energy system (PV)

The figure 15 below illustrates, what factor people emphasized while making purchasing decision of a PV system. Out of the 57 respondents, 44% cared for quality factor of the system, while 37% cared for after sales service. Only 19% of the respondents cared the capital cost factor. This view showed, the rural community cares more of quality after sales service factors while investing in PV system rather than the capital cost of the system. Hence, the reliability of the system and good after sales service could play a major role on wide spreading use of PV system in rural electrification in Thailand. Poor system reliability and poor after sales service of the system will effect the dissemination of PV system in Thailand.

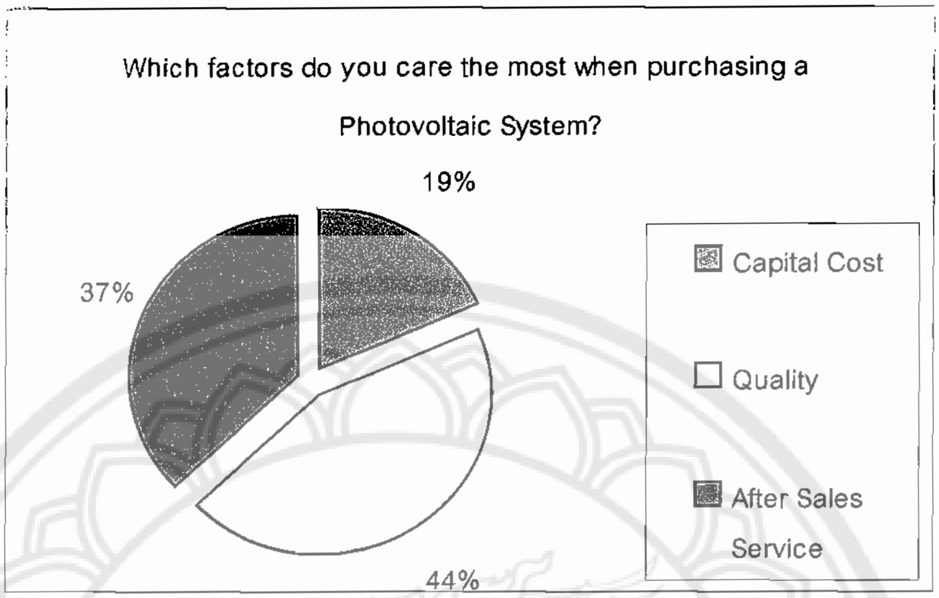

Figure 15 The factors that rural people cared while purchasing PV system.

While asked their biggest concerns of using PV system, 66% of respondents revealed that maintenance is the biggest concern; 17%, 15% and 2% respondents concerned about maintenance, operation and spare parts factors as illustrated in figure 16.

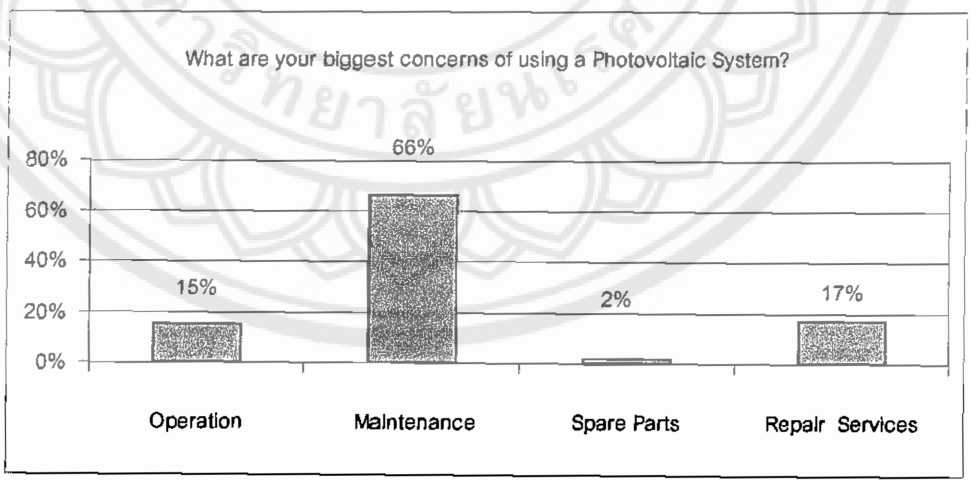

Figure 16 Factor concerned by the users while using PV system

The most of the respondents interviewed (accounting 56%) still preferred grid electricity system for their villages. Figure 17 illustrates the type of electricity supply system preferred by the respondents for electrifying their villages.

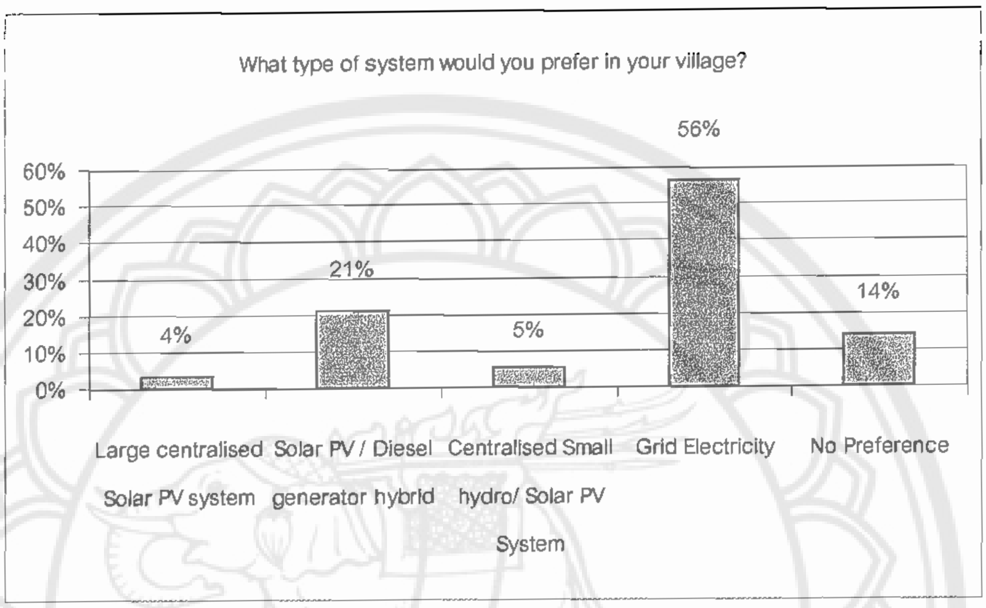

Figure 17 Percentage of Preferred Electricity supply System for Village Electrifications

4.2.4 Importance of Proper Installation, Maintenance of PV Systems and Safety issue

The reliability of any PV system depends upon proper designing; correct installation PV module; proper wiring of the cable, switches, lighting fixtures and sockets. Failure to do installation of PV systems properly; effects the poorer performance of the system and causes frequent failure of the electricity service, hence disappointing the end user. Once proper design and installation is done successfully, PV system operates smoothly requiring very minor maintenance and that too is also not so often. For PV system very minor maintenance is required in 4 to 6 months, which is just adding distilled water in battery and cleaning module if it gets dusty. Besides these minor maintenances PV system doesn't require other maintenance if proper wiring and installation are done.

As PV systems use battery as energy storing medium which is capable of delivering very high current if its terminals are short circuited hence creating high current capable causing fire in wooden/ or straw houses. It is highly recommended to install the battery in safe place with good ventilation, all its terminal well insulated and out of reach children to avoid any possible accident from the battery.

The author has visited few remote villages in rural Thailand, where SHS are installed and observed the system. The present conditions of the PV system installed at Ban Pean village in Chiang Mai province are explained briefly below.

1) Proper Site selection for PV Module Installation

To get the higher output performance from PV it must be installed at a position with less possible shadow occurring place during sunshine hours. At Ban Pean village PV modules are installed on a steel poll with a height of 3 meter from the ground level. As the village is highly forested, the location where PV modules are installed doesn't get enough sunshine as the module gets shadowed by the higher tree. The figure 18 below shows the one of the module installed at Ban Pean Village.

Figure 18 Installation of PV module at location mostly shadowed by trees.

Once solar cells in a PV module are shaded, the output power performance of the PV decreases drastically causing poor power production than rated, which later on will not be not have enough energy to supply the loads. This low energy supply from the battery will supply lesser hour of load operation than the designed hours, hence the users will be disappointed with PV system. So, to give the higher performance of PV system operation, installation of PV module at shadowy space must be avoided.

2) Proper Wiring and location of Battery

Proper wiring and location of battery play very important role in the performance, durability and safety operation of any PV system. Longer wiring from PV module to charge controller should be avoided to decrease the dc voltage drop. In-house wiring should be done with full safety regulation, i.e. while connecting wires, it should be properly insulated. Battery should be installed at well ventilated space covering its terminals with proper insulating caps. Though, these are simple rules to make PV system durable, this was not fully applied in PV system installed at Ban Pean village. Figure 19 illustrates how the battery and wirings are carried out in one of the wooden house at Ban Pean village.

Figure 19 Inappropriate locations of battery and poor wiring.

As seen from figure 19, the battery was installed at inappropriate place like living room or TV room, and also without any safety insulation on battery terminal, which is easily accessible by children. In case of such poor installation of the battery, a circuit of the terminal can cause fire or shock to people if one touches two terminals of battery with bare hands together. A shock from battery terminal can be very fatal causing severe shocks or even to death if the person is physically weak and has weak body resistance.

Similarly, inter-connecting wires must be well insulated to protect any short circuit. But if we look at figure 20 that illustrates how poorly wirings have been done at house of Ban Pean village. It should be noted that the house is made of wood, battery is capable of delivering very high current in case of short circuit and it could easily cause the fire in the house. It is very important to avoid such poor wiring in terms safety reason.

Figure 20 Poor wiring connections without insulation in a house at Ban Pean Village

3) By passing of Charge controller

Charge controller is heart of any PV system, which controls the charge and discharge level of battery at permissible level. Over charging or discharging of lead acid battery decreases the life of battery dramatically, requiring to replacement of battery quicker than its normal life. Author's survey found charge controllers are by passed in many SHS installed in the houses at Ban Pean villages as charge controllers were not working (see figure 21). SHS without charge controller needs more frequent filling of distilled water as battery is overcharged during good sunshine days, and changing of florescent lamps frequently as when they operates at lower voltage, life of tubes decrease. So in summary, when SHS operates without battery charger controller, overall cost of operation and maintenance increases adding extra financial burden to users and making them feel like SHS are not suitable. So in all SHS system a good battery charge controller must be integrated to increase the life of battery.

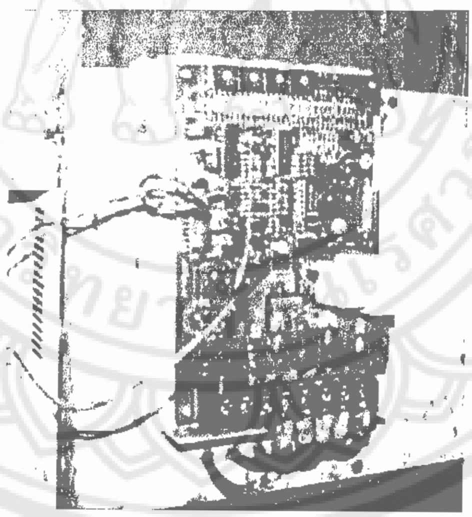

Figure 21 A by passed charge controller in SHS of Ban Pean Village.

4.2.5 Impact on Economy

Still many people think investing in a PV system is not economically viable. The economic implications of learning by doing show that the investment made in the present will be worth of an immense benefit in future. The knowledge gained by the community and children inside the community about renewable system will be more valuable and worthwhile for the future generations. A small investment made from the household savings in PV system would generate income by charging electricity tariffs from the users, which could be accumulated as a community fund for future upgrading of the system as demand of electricity increases. An idea of a green tax can be introduced to stakeholders to raise more community funds for development of the community. A real-life economic growth in the community will make them self reliant, sustainable, and also preserve the environment.

An increase in quality of community health is considered to be growth in productivity and working efficiency. Higher quality of health will increase the involvement of the community to more efficient economic activities, hence reducing poverty and increasing more economic mutual benefit and the economic property of the community.

4.2.6 Policy

The Royal Thai Government adopted its energy policy to promote energy sectors like IPP, SPP; it also introduced an intensive program on RPS. It is expected that with five PV manufacturers producing PV modules, the commercial PV market in the country will be stimulated.

A study was carried out by DEDE on the trend and projection of investment in the establishment of companies involved in solar PV industry. Their assessment is shown in table 20:

Table 20 Investment Trend in the Establishment of Solar PV Industries in Thailand [DEDE]

Company Name	Product	Production (MW/yr)		Technology	Investment (Million Baht)	Start Year	Location (Province)
		Cells	Modules				
Solartron Co. Ltd	Silicon Modules		30	Japanese	120	2004	Nakonratchasima
	Silicon Cells	25		German	1000	2006	
Bangkok Solar Co. Ltd	Amorphous Silicon (Cells & Modules)	5	5	Hungarian	500	2004	Chacheongsao
		10	10		800	2006	
Sharp Thepnakon	Silicon Modules		7	Japanese		2005	Nakornpathom
Thai Agency Engineering Co. Ltd	Amorphous Silicon Modules		10	Japanese		2005	Ayutthaya
Akekarat Solar	Silicon Modules		15	Japanese	200	2005	Rayong
	Silicon Cells	25		German	1400	2006	
TOTAL		65	77				

4.3 Future of Photovoltaic Use for Rural Electrification in Thailand

The future of PV dissemination in Thailand for use in rural villages will largely be decided by the government's policies. Thailand could emulate the example of Philippines with the introduction of a "fee for service" system for electrification, operated by a private company, such as Shell Renewables, with licensing by the government. This would allow the market for PV to develop, while still allowing the government to control licensing. The fee for service system is the best option for the use of photovoltaics for rural electrification, as "people do not want to pay for solar equipment; they want to pay for electrical services."

Solar home systems are another good option for Thailand. If they continue to be distributed to the villagers free of charge as part of government demonstration projects as they have been in the past, the government should take careful steps to ensure that there is adequate follow up with the maintenance of the project. In all cases, whether or not the government is distributing the Solar Home System (SHS) or other PV technologies, standards testing needs to be carried out to ensure that the products being supplied are of high quality.

Hence to satisfy the growing demand of energy in a community, a PV hybrid system can be designed by integrating an agriculture machine to supply the more reliable power to the community, with the introduction of a community micro grid. Such a PV hybrid system can also be integrated with micro-hydro or bio-diesel generators and supply the community with a decentralized micro-grid to provide more reliable power supply. Such a hybrid system can provide more satisfying electricity to the community as the demands increase. In other hand, grid connected PV systems can be the best choice for urban areas to reduce the electricity bill as well as to supply the pick loads demand during the day time, hence enhancing the social image of being a renewable energy user.

Overall, Thailand has a good opportunity to take advantage of its sunny location to electrify its remaining unelectrified villages. Renewable Energy Service Companies (RESCOs) will be the best use of solar energy technology in Thailand if they can be implemented, and SHS is another good option for rural off-grid electrification. With careful planning, oversight, and a long term commitment to the people, which the government of Thailand has proven to have, the use of solar energy technology will be very successful for rural electrification in Thailand

4.4 An ideal approach used to evaluate the integrated energy supply and economic evaluation

Based on collected information, theories and experiences gained from this study, a normative analysis model is presented with collaboration of data by paradigm shift and recommended for PV Rural Electrification (PRE) as illustrated in Figure 22.

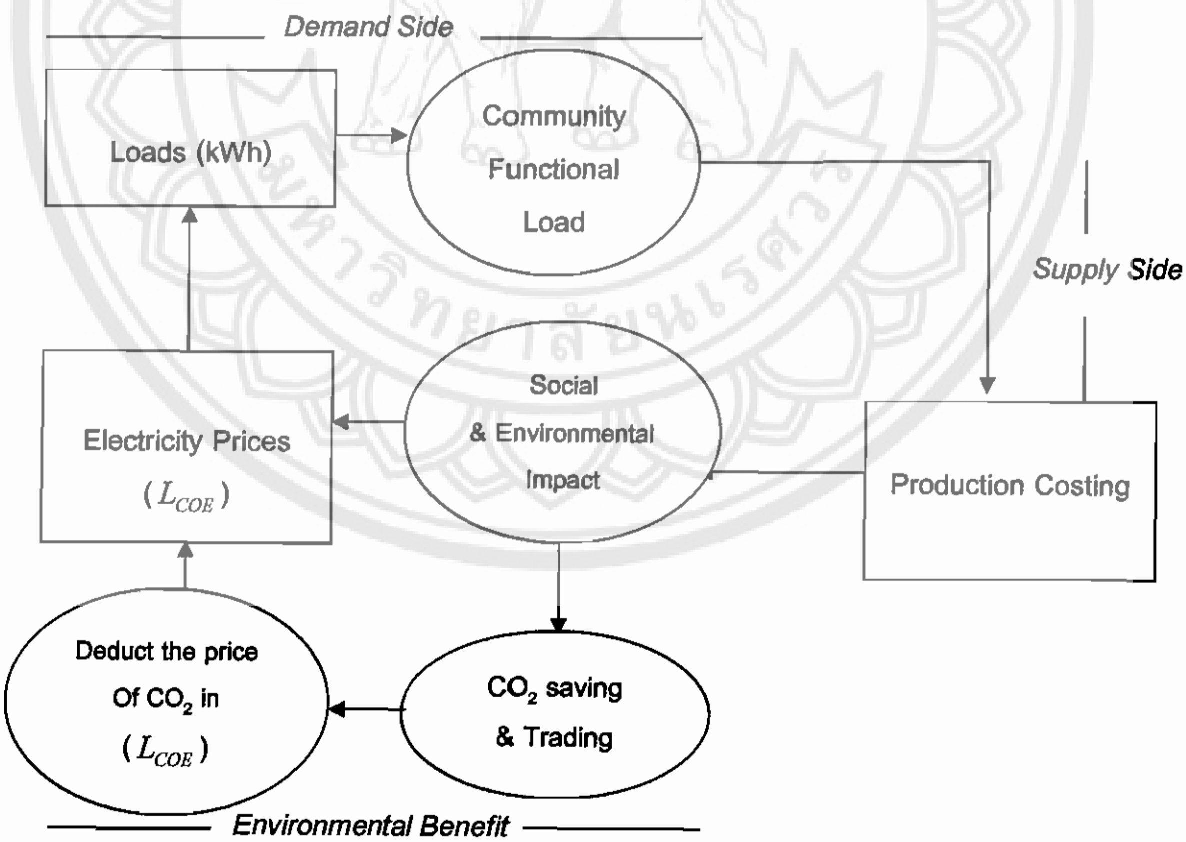

Figure 22 PV Rural Electrification Model (PRE-Model)

Based on site surveys and interviews about the users of PV system in many villages in Thailand, this model is being introduced for selecting the appropriate type of PV technology for different part of the rural areas with unique geographical as well as societal conditions. To initiate any PV project for rural electrification in Thailand, a study of basic load profile of society must be studied. Depending upon the type of society and culture behavior the communal functional load may vary for different rural community which must be considered and study well before kicking of any project and do system sizing, and calculation energy costing. The higher cost of energy production by PV doesn't make any project unviable. Social and environmental benefits that a PV rural electrification system can give also are to be taken as major contributions to society as well as whole country. The amount of CO_2 saved by the PV system could be a good model project for contributing Thailand's CDM ratification. Amount of carbon CO_2 saved can sell into carbon fixing market in the world which could contribute reduction of life cycle cost of electricity produced by any PV project. So in a broader sense, the life cycle cost of electricity produced by PV rural electrification project should be evaluated using the PRE model.

4.4.1 Economic Evaluation of Different type of PV system under taken for this study work

Based on same load profile, different PV systems such as SHS, BCS and CMG are considered for economic evaluation and cross comparison was carried out with Diesel Generator system for rural electrification. All economic parameters undertaken for calculation are same for all the systems. Figure 23 illustrates the different costs associated with different types of PV system as well and diesel generator system.

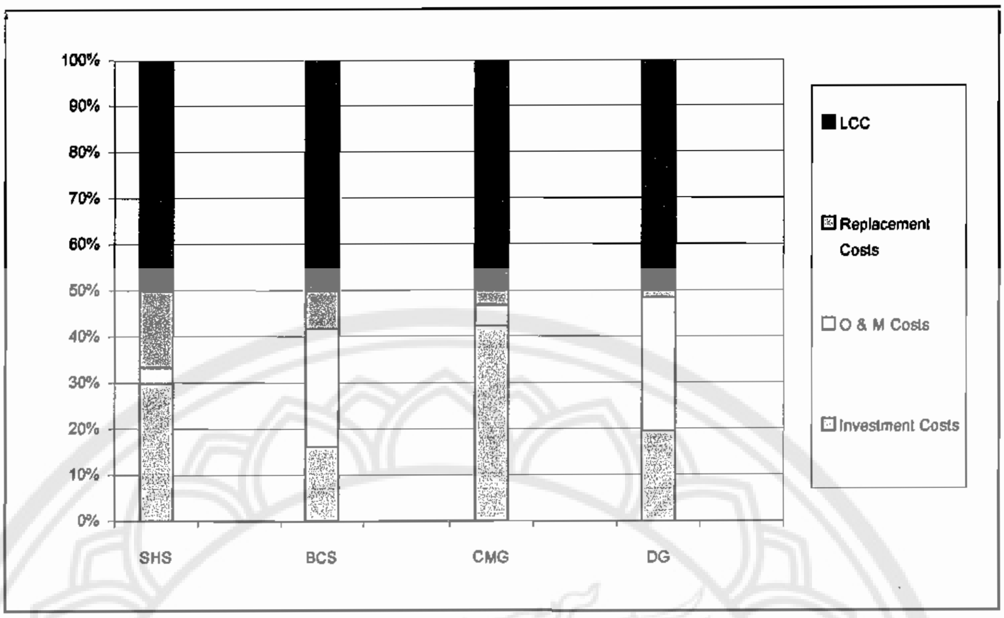

Figure 23 Different Costs Associated with PV and Diesel Generator system.

From the figure it can be concluded that operation and maintenance cost of SHS is the lowest while diesel generator system has the highest operation and maintenance cost.

The cost of replacing some of the system components also involves an additional 5% of the component cost as labor expenses (estimated). Figure 24 illustrates the life cycle cost of different PV system compared with diesel generator system.

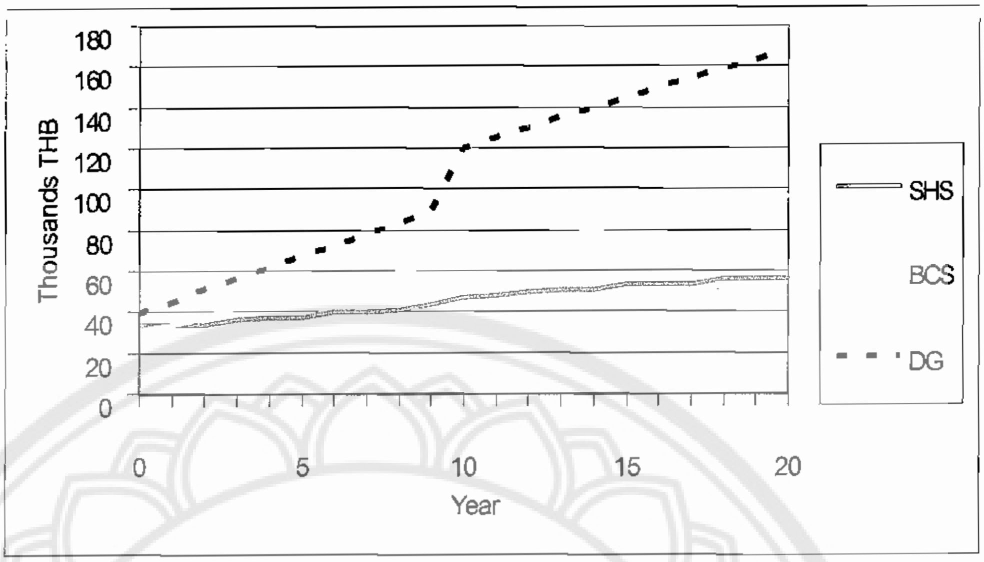

Figure 24 Life Cycle Cost of PV systems compare with DG

The results of LCC calculation for SHS, BCS, CMG and DGS were found to be THB 56,476, 69,989, 861,627 and 167,321 respectively. The Life Cycle Unit Energy Costs for each of the system were found to be THB 26, 45, 57 and 11 for each of the system respectively. The unit cost of diesel generator system seems to be the cheapest one but still environmental concerns should also be considered.

Detailed tabulated calculation of the LCC for all SHS, BCS, CMG and DG systems are shown in Annex.

The cost of electricity generated by diesel generator was found to be the lowest, but still another social as well as environmental consequences that might be caused by diesel generator and reliability of fuel supply in remote areas should be given due consideration. From the study SHS systems were found to be more suitable for scattered rural household electrification. As SHS systems are individual user dependent and if one user miss uses the system, it doesn't affect the other SHS in the community.

Figure 25 illustrates the transition on life cycle cost of unit energy produced by each of the system under study with the effect of number of house holds in the community. Similarly, figure 26 illustrates the percentage of each L_{COE} contributed by different categories of rural electricity supply system affected varying number of house holds in rural communities. As can be seen from the chart that the L_{COE} of SHS remains almost constant regardless of the number of house holds in a community. For the community more than 50 household the L_{COE} of CMG or DG have affects from number of house holds in the community. But still, scatter ness of settlement still to be considered.

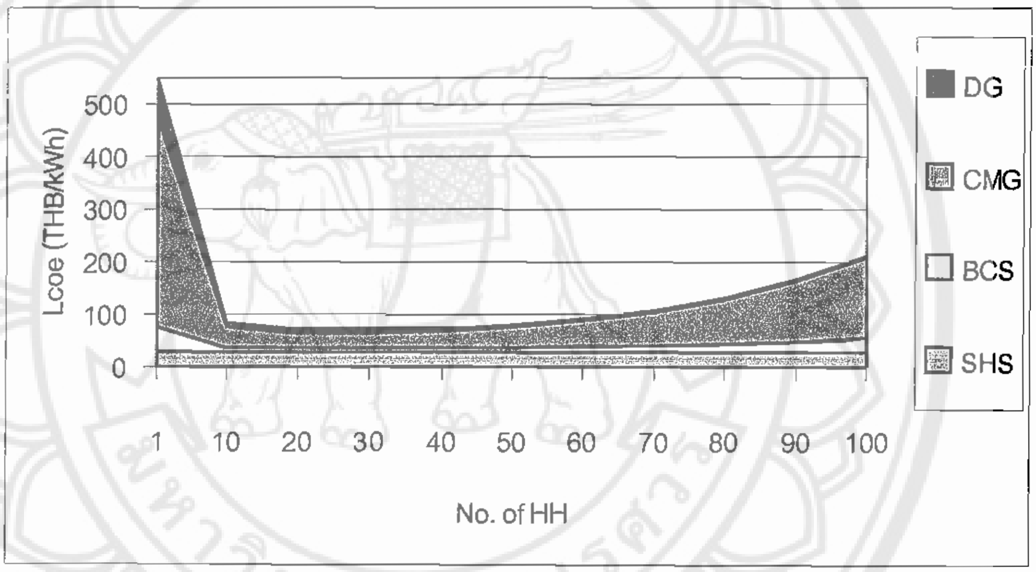

Figure 25 Area chart in L_{COE} of rural electricity supply system

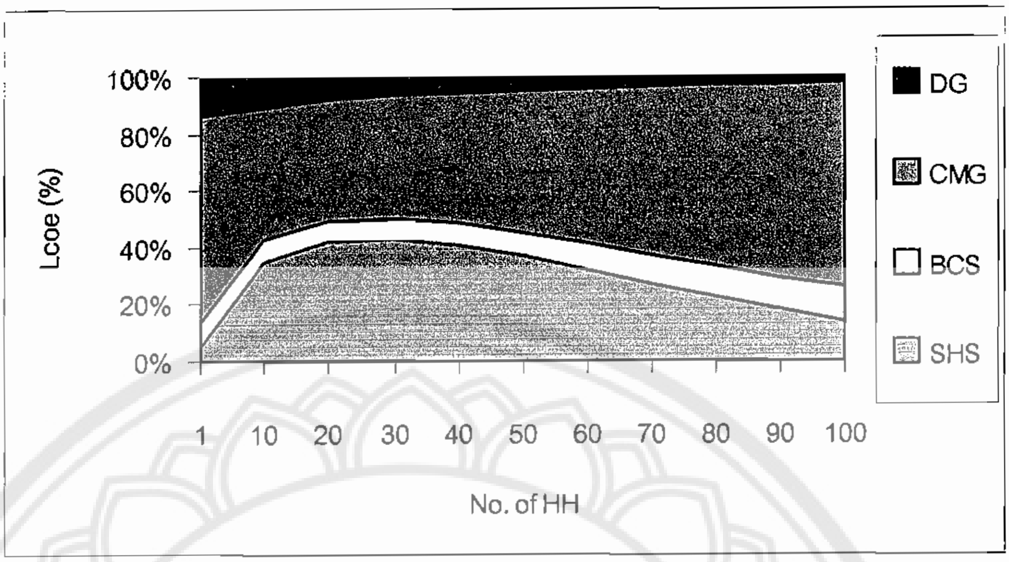

Figure 26 The trend of the percentage of each L_{COE} contributed by different categories of rural electricity supply system with respect of No of HH in the community.

Centralized Mini-Grid system might not be a suitable for widely scattered settlement of the rural people because of the cost of mini-grid extension. Though min-grid system well designed with protection system, miss using of load or miss handling of electrical appliances by one user would make whole system down putting whole community in out of electricity services.

Even though, battery charging stations are widely disseminated in rural electrification in Thailand, it is not very practical to carry heavy battery to distantly located charging station and carry back home. Frequent connecting and disconnecting of battery from the system might cause loose connection casing sparks good enough to cause a unwanted fire. While carrying to charging station and back to home, spill over of acid could case damages to skin or fabrics. Frequent moving of the battery can also reduce the battery life hence adding extra burden of cost to user.

4.4.1 Environmental benefits of Using PV by saving the CO2 Emission from Fossil Fuel

Use of renewable energy system for rural electrification saves use of fossil fuels for lighting purpose. Based on assumption and calculation made in Section 3.8 for fuel oil savings, it was found that annual kerosene of 16.8 litres / HH can be saved. Similarly, in case of diesel, annually 109.9294 litres / HH of diesel use can be saved. By saving the use of fossil fuel about 20,416.8 kg of over the life cycle of the SHS per household (at 2005 CO_2 emission rates). Therefore, combining the two CO_2 savings, the total estimated annual avoided CO_2 emission found to be 1,300.39 kg of CO_2 per year (for kerosene) and 1,305.27 kg of CO_2 per year (for diesel). This will be a small, but meaningful contribution towards Thailand's Clean Development Mechanism (CDM) and an addition to its Carbon Emission Reduction credit.

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, results of research are discussed based on site survey, interviews with end-users and economic calculation that were being made during this research work.

4.1 Empirical results of the Photovoltaic system's survey

4.1.1 Renewable Energy for Sustainable Development

To enhance the sustainability of electricity supply by photovoltaic systems, the two following aspects should be considered:

1) Suitability of renewable energy provided to community

- Villagers should be familiar with the selected technology.
- Villagers should have some experiences on this selected technology and know accurately how to operate with it.
- Villagers have an acceptance on this selected technology.
- Villagers should be able to conduct the system maintenance by themselves.
- There should spare parts and skilled technician taking in charge of equipment when equipment fails or damaged.

2) Readiness and acceptance of villager on the related changes

In order to make any renewable system sustainable and long serving to the villagers or community, following points should be satisfied first:

- Villagers desire of electricity supply and satisfy with the selected technology.
- Willingness to pay for the maintenance fee of electrical equipment Within their house.
- Willingness to pay for system maintenance fee.
- Willingness to co-invest on the necessary equipment.

Besides considering from the two above-mentioned aspects, it is necessary to establish an organization responsible for evaluating the system design, installation, operation and monitoring in order to improve the sustainability of photovoltaic system.

4.1.2 Advantage and Disadvantage of Various Photovoltaic Systems

Each technology has advantages and disadvantages to the user, the installer and system performance. Followings are the listings of the principal advantages and disadvantages associated with following three different systems analyzed for rural electrifications options:

- Centralized Diesel System
- Centralized Solar System
- Individual Solar Home System

1) Centralized Diesel System

Advantages	Disadvantages
- Lowest initial system cost. - Rapid speed in responding fluctuations in the loads. - Takes short time to start and supply to system. - Rapid, simple shut down process. - Moderate in bulk and weight.	- Fuel requires use of foreign exchange. - Generally, fuel expensive, not easily available as it is dependent on shipping and foreign supplier. - Storing fuel can be bulky depending upon the remoteness of the location and can be also risky. - Replacement parts are not easily available and people may not have much knowledge of the parts. - Higher level of operator's training is required as there are too many mechanically moving parts. - Foreign political situation controls over fuel prices. - Noise, noxious smoke emission which is unhealthy and having bad smell. - Fossil fuel is toxic and may damage land and sea environment in case of spill out. - Short useful life of machinery. - Functions inefficiently and with higher maintenance requirements at lighter loads.

Advantages	Disadvantages
	- Relatively high training and maintenance cost. - A skilled operator is required to operator the complex mechanical system.

2) Centralized Solar System

Advantages	Disadvantages
- No fossil fuel requires. - Instantaneous response to load changes with excellent voltage and frequency regulation, in case the system is oversized than the load profile of the remote areas. - Unattended operation. - No moving mechanical components. - Less environmental impacts. - System is more reliable as long as system is designed based upon the load profile community.	- High capital requirement. - Highly trained electronic technician required for maintenance. - Spare parts are not easily available. - Limited system experience rather than monitored demonstration projects. - Requires a large, shade free area. - Power supply capacity is weather dependent.

3) Individual Solar Home System

Advantages	Disadvantages
- Simple proven designs are available. - Less service required and easily serviceable when required. - Components are modular and few in numbers. - Less training is needed for installer and field maintenance. - System size is modular and can be modified according to load demand. - Moderate capital cost (high component cost but no grid extension cost). - Readily available spare parts. - Individually dependent system rather than centralized system. - It is modular and easily modifiable to accommodate changes in load requirement. - Rapid installation possible. - Very less environmental impact. - No noise or harmful smoke emission. - Little change in efficiency with the fluctuations of load. - Simple design and maintenance can be done locally. - No fossil fuel required.	- Power availability somewhat dependent on the weather. - Requires shade free mounting location. - Requires more customer attention and training than other systems.

Analyzing the advantages and disadvantages of each of available technologies to electrify the rural communities, we can rank the appropriate generation technologies as:

INDIVIDUAL SYSTEMS

- Only solar photovoltaic home system should be considered as it is solely

dependent on individual users how they use the system and doesn't affect in the performance of the system by the another end user unlike in case of centralized system.

CENTRALISED SYSTEMS

- Centralized solar systems should be considered where the system is competitive

in cost with micro-hydro, or diesel or small biomass system.

The first consideration for new rural electrification should be the extension of an existing grid. Generally reliability, power capacity and lower operating cost of grid supply make it the lowest cost option compared to all other rural electricity supply options. Initial capital cost, however, may be too high to be justified and individual or community electrical supply systems necessary.

Where the grid extension is too costly and stand-alone system must be installed, the primary choice is between central power and individual solar power. Where the load is almost exclusively domestic, individual power systems are clearly technically and socially superior to any central system. Individual systems are usually also financially superior unless the houses are very close together, a community grid already exists or a grid extension to that community can reasonably be expected to occur within five years of the initial installation.

Where a significant industrial or commercial load exists within the community, the decision to interconnect all consumers with a central power source or to keep the commercial and the domestic loads separate must be made on the basis of (1) the type of commercial load (2) the timing of the commercial and the domestic load peaks, and (3) the relative scale of the commercial and the domestic loads.

4.2 Evaluation of Impacts of Photovoltaic Rural Electrification Systems in Thailand

Rural electrification has effects on economy, society, knowledge, etc., of people in the villages or households where it is introduced. But, many researchers and experts have observed that the economic benefits of rural electrification are not as great as the social benefits. Additionally, in some cases, the benefits of electricity do not outweigh the expense of the electricity.

Two positive economic effects of rural electrification are: 1) electricity can power machines that make the labor of farmers and small-scale manufacturers easier and more efficient and, 2) lighting that lasts longer in the evening can extend longer opening of stores and increase sales for small shops in the village as well as the longer economic activities in the each households. These changes may give the village's economy a small boost. The electricity is just one of the many necessary factors for an economic development initiative to be successful. In places where many of these variables are not present, electricity will not spur an economic boom. Yet, in areas where many or all of the elements of successful economic development are present and with the lack of electricity being the limiting factor, the introduction of electricity will certainly benefit the local economy.

Another important economic aspect to be considered is whether or not the rural community that is receiving electricity has the cash flow available to fund an electrification project. In most rural villages, there is a very limited amount of cash available and there are few, if any, sources of cash coming into the community. Rural electrification can be in a drain if the village has already limited cash supply because the village is paying outside of the community for the use of electricity or for the equipment to generate their own. Thus a rural electrification project will have a negative economic impact on the community unless the community has adequate cash on hand and cash flowing in as well as out.

The impact of electrification on the rural economy is a mix of positive and negative effects. The most successful introduction happens in a community where there is already sufficient economic development in place to support the costs of electrification and to fully take advantage of the opportunities that electricity can provide.

4.2.1 Social Impacts

The Thai Government's 9th National Economic and Social Development Plan (NESDP) has emphasized the promotions of local and community participation to improve the management mechanism of natural resources and the environment at the community level, so as to achieve social approval of energy security. Once the rural community has secured a reliable electricity supply, they can have access to modern communication media like TV and radios, which can play a vital role in creating a knowledge-based society. Improved electricity supply also generates extra economic activities in the community, improving the capacity-building of the poor. Overall extra economic activities in each house-hold in the community increase the capital development of community as a whole. Due to improvement in lighting and information dissemination, there would be improvement in community health. With reliable electricity supply in the community, all modern gadgets will be operational in the community, increasing extra creativity and fostering community's well-being.

4.2.2 Modern media

PV systems such as off-grid or individual solar home system are playing major role in electrifying the remote communities. There is no doubt that once people have an access to electricity, they will have access to modern mass media communication. Because of the clean light they are having due to solar energy will also give them more time to spend in economic, social, educational activities even at late night. Without electricity villages would be silent by it gets dark. By using electricity, the massive reduction in dry cell battery can be seen, unless otherwise villager will be using for their transistor radios and which possesses environmental threat as rural communities doesn't have much of knowledge about battery disposal in their communities. Government has many TV and Radio programmes transmitted targeting the rural communities for their economic development at grass-root level. For the places where central grid cannot expect reach with 5 or 10 years of time due to remoteness and scattered settlement of the communities and uneconomic grid extension cost, so only possible solution remaining is to utilize PV systems like micro or mini-grid or solar home system to provide electricity in competitive cost. PV powered school also can teach computer education and give to internet access in remote schools of the country, letting the pupils to access the vast information sources of the modern cyber network. In remote school such facilities must be installed soonest possible otherwise there will be gap oh knowledge between pupils from remote and urban schools. Table 19 below shows the number of computer and internet users in Thailand.

Table 19 Computer and Internet Users in Thailand, 2004

(Unit: In thousand)

Region	To use computer	To use internet
Whole Kingdom	12,542.80	6,971.50
Municipal	6,438.60	4,155.70
Non-municipal	6,104.20	2,815.80

Source: Statistical Year Book Thailand 2004.

As indicated by table, the most of the internet and computer users are in municipal area. And lesser users are in non municipal areas. The rural places where there is no electricity, the people are deprived of such and electronic mass media communication system, hence increasing the knowledge gap among urban and rural communities. To make a country a well develop in terms of economy and social status, living standard, the government must try to fill this knowledge gap, and make rural community self sufficient in economy wise at grass root level.

Based on sample survey interviewed with 57 respondents, it showed that 91% of respondent revealed that they watch television for entertainment and other useful news and information. They survey also showed that 68% children of total interviewed respondents watch television for entertainment. Figure 10 illustrates the number of watching television for their entertainment and other useful information.

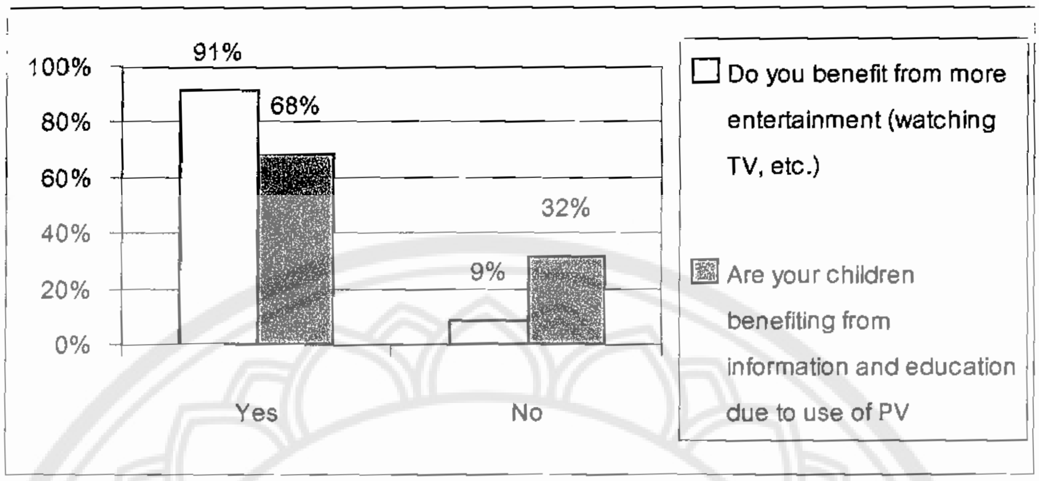

Figure 10 Number of People watching television for their entertainment and other information

The survey also showed that only 5% of the total 57 respondent viewed very satisfied, 40% satisfied, 32% accepted, 21% not satisfied and 2% do not care with the quality of electricity supplied by SHS as illustrated in Figure 11.

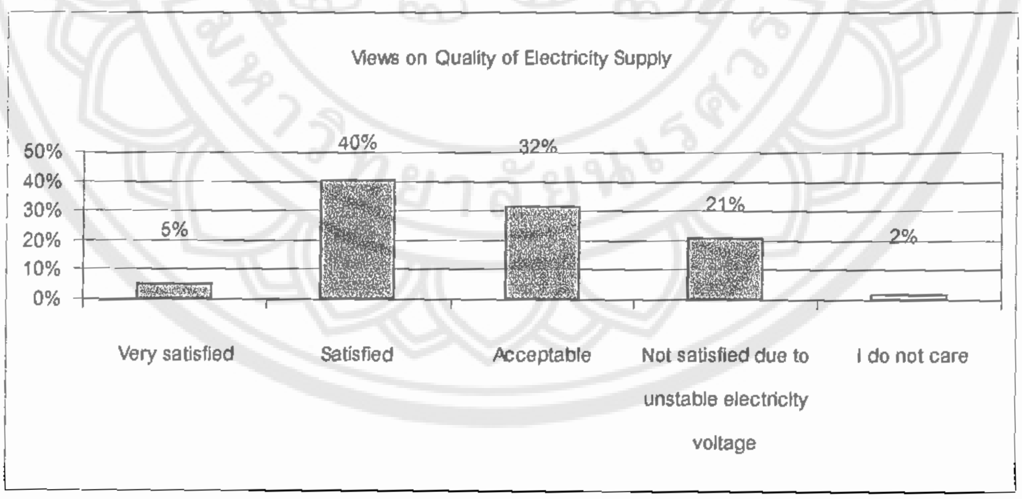

Figure 11 Respondents views on quality of electricity supply by SHS.

When asked, which kind of electricity supply do they prefer? Ninety percent of respondents preferred grid electricity. While 8% preferred PV power and rest 2% diesel/Petrol generator system as illustrated in figure 12 below:

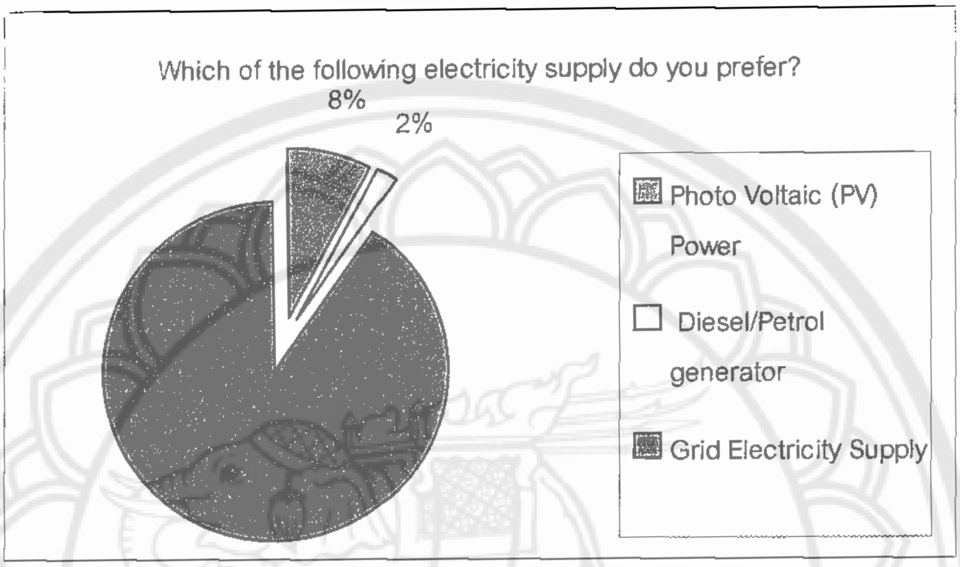

Figure 12 Preferred Electricity Supply System in Rural Thailand.

4.2.3 Attitude

It's human attitude or nature to wish or expect for a better and improved life-style. Same thing implies for rural communities. The community's growing needs and wants will never stops. In such a case, the community's attitude towards solar or other rural electricity supply system might change once the system fails to supply sufficient power to the community. Good knowledge about the system that is being installed in the community must be given to the people in the community. It is necessary to let them know the benefits and limitations of the system and make them interested in it for longer life the system. Without the interest and willingness of the community, any community electricity system may fail in short term. In figure 13, it is illustrated the number of respondents view on different benefits from PV systems.

4.2.4 Impact on Economy

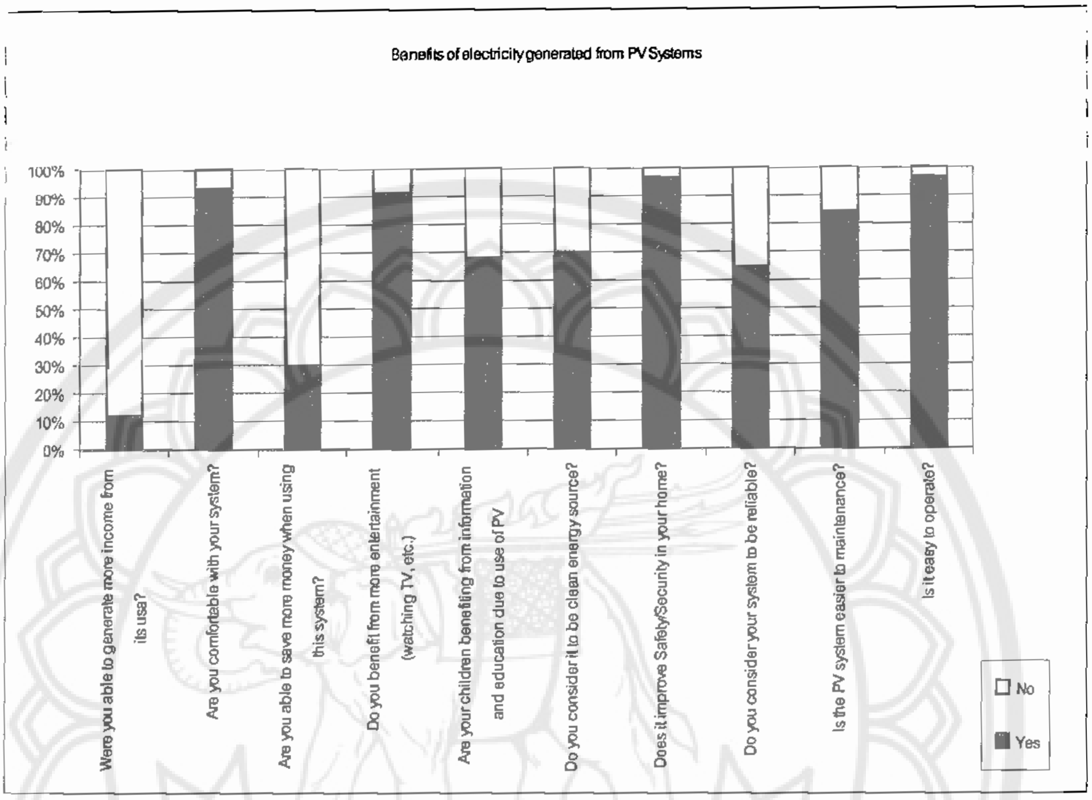

Figure 13 Benefit of Electricity Generated from PV Systems.

For different questions people tend to have different answer and opinion depending upon personal attitude. As mentioned above, 57 persons were sample interviewed and different people have different opinion for the same query asked by the author.

When asked, how you would like to pay for alternative energy source (PV), 57% of the respondent didn't response. This might be because the systems they are using are all free of charge. Twenty three percent (23%) and 9% of respondents were willing to pay in 2 and installments respectively. Nine percent of respondents willing to pay by lump sum method, while 2 percent willing to pay by leas purchase method as illustrated in figure 14.

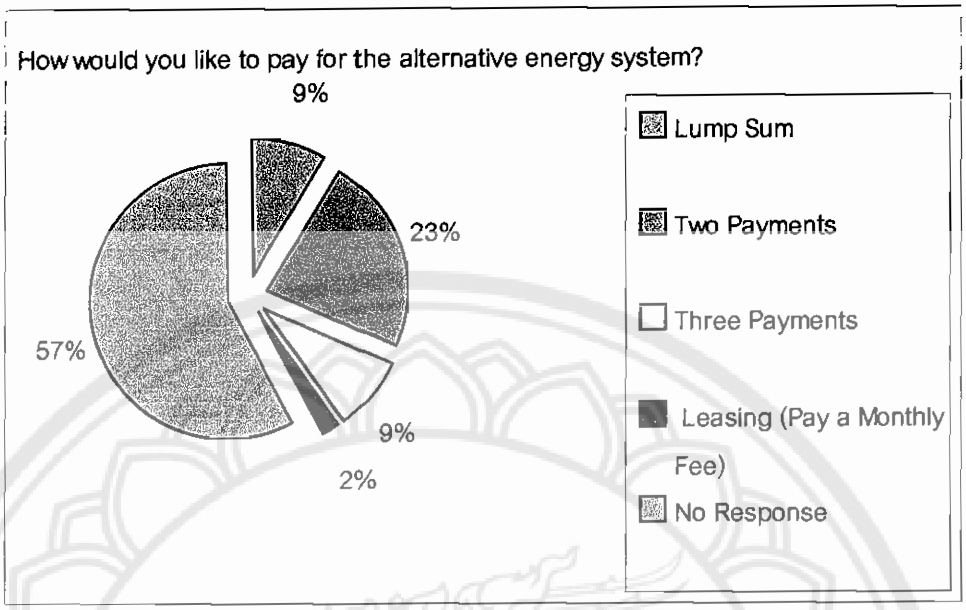

Figure 14 Percentage of respondents willing to pay with different payment method for alternative energy system (PV)

The figure 15 below illustrates, what factor people emphasized while making purchasing decision of a PV system. Out of the 57 respondents, 44% cared for quality factor of the system, while 37% cared for after sales service. Only 19% of the respondents cared the capital cost factor. This view showed, the rural community cares more of quality after sales service factors while investing in PV system rather than the capital cost of the system. Hence, the reliability of the system and good after sales service could play a major role on wide spreading use of PV system in rural electrification in Thailand. Poor system reliability and poor after sales service of the system will effect the dissemination of PV system in Thailand.

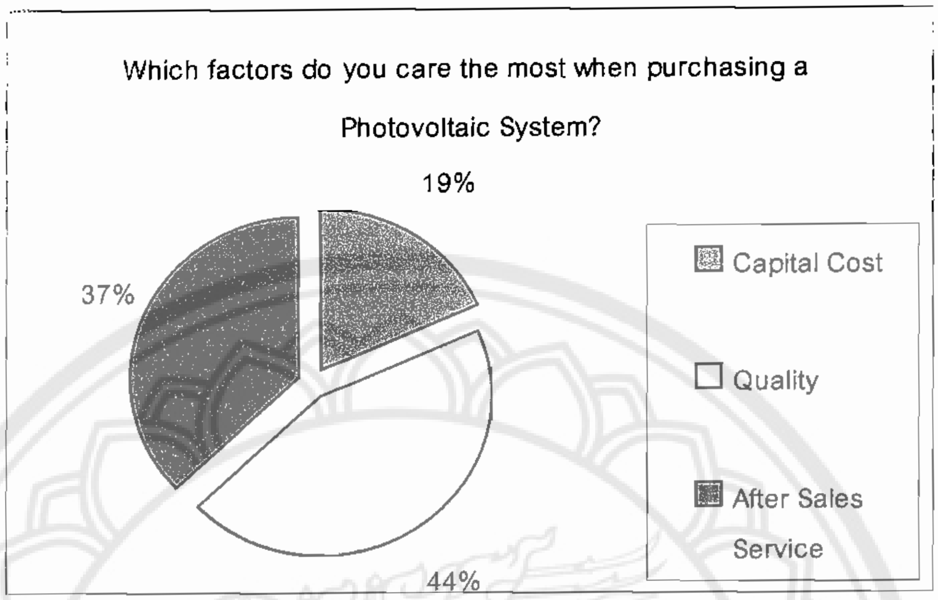

Figure 15 The factors that rural people cared while purchasing PV system.

While asked their biggest concerns of using PV system, 66% of respondents revealed that maintenance is the biggest concern; 17%, 15% and 2% respondents concerned about maintenance, operation and spare parts factors as illustrated in figure 16.

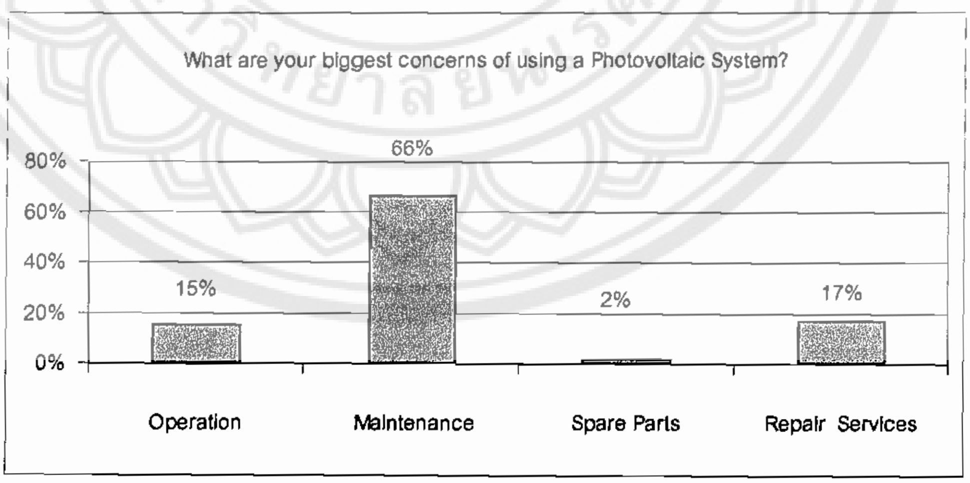

Figure 16 Factor concerned by the users while using PV system

The most of the respondents interviewed (accounting 56%) still preferred grid electricity system for their villages. Figure 17 illustrates the type of electricity supply system preferred by the respondents for electrifying their villages.

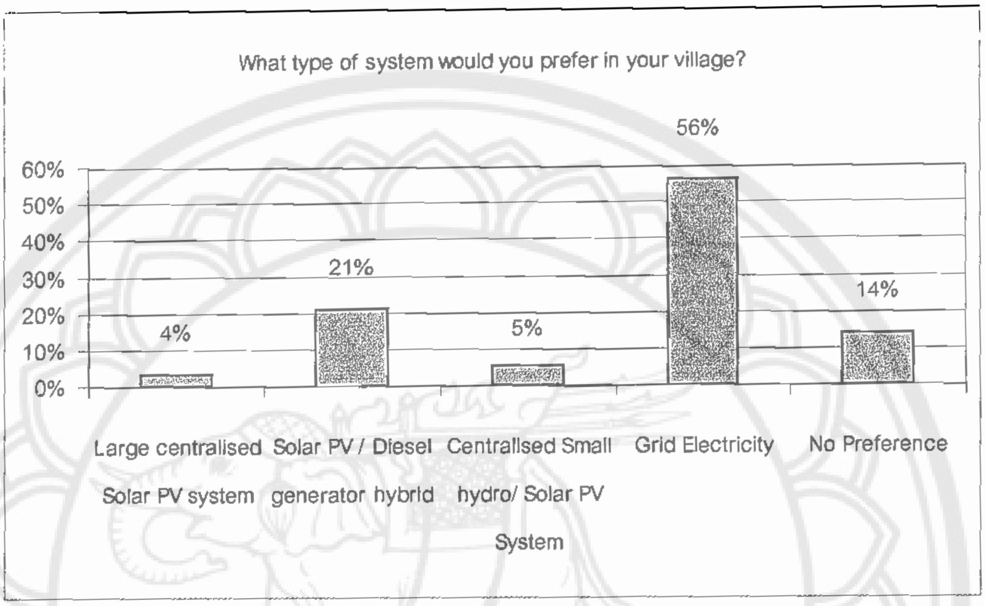

Figure 17 Percentage of Preferred Electricity supply System for Village Electrifications

4.2.4 Importance of Proper Installation, Maintenance of PV Systems and Safety issue

The reliability of any PV system depends upon proper designing; correct installation PV module; proper wiring of the cable, switches, lighting fixtures and sockets. Failure to do installation of PV systems properly; effects the poorer performance of the system and causes frequent failure of the electricity service, hence disappointing the end user. Once proper design and installation is done successfully, PV system operates smoothly requiring very minor maintenance and that too is also not so often. For PV system very minor maintenance is required in 4 to 6 months, which is just adding distilled water in battery and cleaning module if it gets dusty. Besides these minor maintenances PV system doesn't require other maintenance if proper wiring and installation are done.

As PV systems use battery as energy storing medium which is capable of delivering very high current if its terminals are short circuited hence creating high current capable causing fire in wooden/ or straw houses. It is highly recommended to install the battery in safe place with good ventilation, all its terminal well insulated and out of reach children to avoid any possible accident from the battery.

The author has visited few remote villages in rural Thailand, where SHS are installed and observed the system. The present conditions of the PV system installed at Ban Pean village in Chiang Mai province are explained briefly below.

1) Proper Site selection for PV Module Installation

To get the higher output performance from PV it must be installed at a position with less possible shadow occurring place during sunshine hours. At Ban Pean village PV modules are installed on a steel poll with a height of 3 meter from the ground level. As the village is highly forested, the location where PV modules are installed doesn't get enough sunshine as the module gets shadowed by the higher tree. The figure 18 below shows the one of the module installed at Ban Pean Village.

Figure 18 Installation of PV module at location mostly shadowed by trees.

Once solar cells in a PV module are shaded, the output power performance of the PV decreases drastically causing poor power production than rated, which later on will not be not have enough energy to supply the loads. This low energy supply from the battery will supply lesser hour of load operation than the designed hours, hence the users will be disappointed with PV system. So, to give the higher performance of PV system operation, installation of PV module at shadowy space must be avoided.

2) Proper Wiring and location of Battery

Proper wiring and location of battery play very important role in the performance, durability and safety operation of any PV system. Longer wiring from PV module to charge controller should be avoided to decrease the dc voltage drop. In-house wiring should be done with full safety regulation, i.e. while connecting wires, it should be properly insulated. Battery should be installed at well ventilated space covering its terminals with proper insulating caps. Though, these are simple rules to make PV system durable, this was not fully applied in PV system installed at Ban Pean village. Figure 19 illustrates how the battery and wirings are carried out in one of the wooden house at Ban Pean village.

Figure 19 Inappropriate locations of battery and poor wiring.

As seen from figure 19, the battery was installed at inappropriate place like living room or TV room, and also without any safety insulation on battery terminal, which is easily accessible by children. In case of such poor installation of the battery, a circuit of the terminal can cause fire or shock to people if one touches two terminals of battery with bare hands together. A shock from battery terminal can be very fatal causing severe shocks or even to death if the person is physically weak and has weak body resistance.

Similarly, inter-connecting wires must be well insulated to protect any short circuit. But if we look at figure 20 that illustrates how poorly wirings have been done at house of Ban Pean village. It should be noted that the house is made of wood, battery is capable of delivering very high current in case of short circuit and it could easily cause the fire in the house. It is very important to avoid such poor wiring in terms safety reason.

Figure 20 Poor wiring connections without insulation in a house at Ban Pean Village

3) By passing of Charge controller

Charge controller is heart of any PV system, which controls the charge and discharge level of battery at permissible level. Over charging or discharging of lead acid battery decreases the life of battery dramatically, requiring to replacement of battery quicker than its normal life. Author's survey found charge controllers are by passed in many SHS installed in the houses at Ban Pean villages as charge controllers were not working (see figure 21). SHS without charge controller needs more frequent filling of distilled water as battery is overcharged during good sunshine days, and changing of florescent lamps frequently as when they operates at lower voltage, life of tubes decrease. So in summary, when SHS operates without battery charger controller, overall cost of operation and maintenance increases adding extra financial burden to users and making them feel like SHS are not suitable. So in all SHS system a good battery charge controller must be integrated to increase the life of battery.

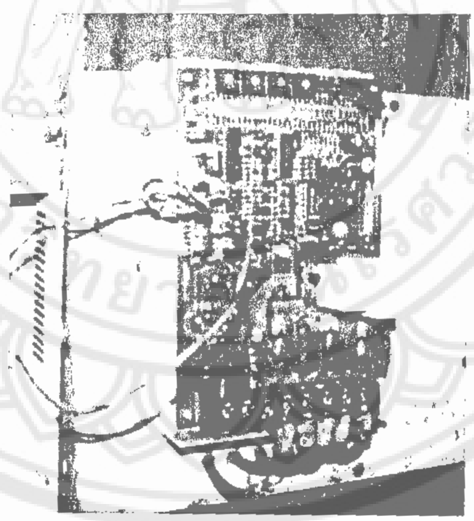

Figure 21 A by passed charge controller in SHS of Ban Pean Village.

4.2.5 Impact on Economy

Still many people think investing in a PV system is not economically viable. The economic implications of learning by doing show that the investment made in the present will be worth of an immense benefit in future. The knowledge gained by the community and children inside the community about renewable system will be more valuable and worthwhile for the future generations. A small investment made from the household savings in PV system would generate income by charging electricity tariffs from the users, which could be accumulated as a community fund for future upgrading of the system as demand of electricity increases. An idea of a green tax can be introduced to stakeholders to raise more community funds for development of the community. A real-life economic growth in the community will make them self reliant, sustainable, and also preserve the environment.

An increase in quality of community health is considered to be growth in productivity and working efficiency. Higher quality of health will increase the involvement of the community to more efficient economic activities, hence reducing poverty and increasing more economic mutual benefit and the economic property of the community.

4.2.6 Policy

The Royal Thai Government adopted its energy policy to promote energy sectors like IPP, SPP; it also introduced an intensive program on RPS. It is expected that with five PV manufacturers producing PV modules, the commercial PV market in the country will be stimulated.

A study was carried out by DEDE on the trend and projection of investment in the establishment of companies involved in solar PV industry. Their assessment is shown in table 20:

Table 20 Investment Trend in the Establishment of Solar PV Industries in Thailand [DEDE]

Company Name	Product	Production (MW/yr)		Technology	Investment (Million Baht)	Start Year	Location (Province)
		Cells	Modules				
Solartron Co. Ltd	Silicon Modules		30	Japanese	120	2004	Nakonratchasima
	Silicon Cells	25		German	1000	2006	
Bangkok Solar Co. Ltd	Amorphous Silicon (Cells & Modules)	5	5	Hungarian	500	2004	Chacheongsao
		10	10		800	2006	
Sharp Thepnakon	Silicon Modules		7	Japanese		2005	Nakornpathom
Thai Agency Engineering Co. Ltd	Amorphous Silicon Modules		10	Japanese		2005	Ayutthaya
Akekarat Solar	Silicon Modules		15	Japanese	200	2005	Rayong
	Silicon Cells	25		German	1400	2006	
TOTAL		65	77				

4.3 Future of Photovoltaic Use for Rural Electrification in Thailand

The future of PV dissemination in Thailand for use in rural villages will largely be decided by the government's policies. Thailand could emulate the example of Philippines with the introduction of a "fee for service" system for electrification, operated by a private company, such as Shell Renewables, with licensing by the government. This would allow the market for PV to develop, while still allowing the government to control licensing. The fee for service system is the best option for the use of photovoltaics for rural electrification, as "people do not want to pay for solar equipment; they want to pay for electrical services."

Solar home systems are another good option for Thailand. If they continue to be distributed to the villagers free of charge as part of government demonstration projects as they have been in the past, the government should take careful steps to ensure that there is adequate follow up with the maintenance of the project. In all cases, whether or not the government is distributing the Solar Home System (SHS) or other PV technologies, standards testing needs to be carried out to ensure that the products being supplied are of high quality.

Hence to satisfy the growing demand of energy in a community, a PV hybrid system can be designed by integrating an agriculture machine to supply the more reliable power to the community, with the introduction of a community micro grid. Such a PV hybrid system can also be integrated with micro-hydro or bio-diesel generators and supply the community with a decentralized micro-grid to provide more reliable power supply. Such a hybrid system can provide more satisfying electricity to the community as the demands increase. In other hand, grid connected PV systems can be the best choice for urban areas to reduce the electricity bill as well as to supply the pick loads demand during the day time, hence enhancing the social image of being a renewable energy user.

Overall, Thailand has a good opportunity to take advantage of its sunny location to electrify its remaining unelectrified villages. Renewable Energy Service Companies (RESCOs) will be the best use of solar energy technology in Thailand if they can be implemented, and SHS is another good option for rural off-grid electrification. With careful planning, oversight, and a long term commitment to the people, which the government of Thailand has proven to have, the use of solar energy technology will be very successful for rural electrification in Thailand

4.4 An ideal approach used to evaluate the integrated energy supply and economic evaluation

Based on collected information, theories and experiences gained from this study, a normative analysis model is presented with collaboration of data by paradigm shift and recommended for PV Rural Electrification (PRE) as illustrated in Figure 22.

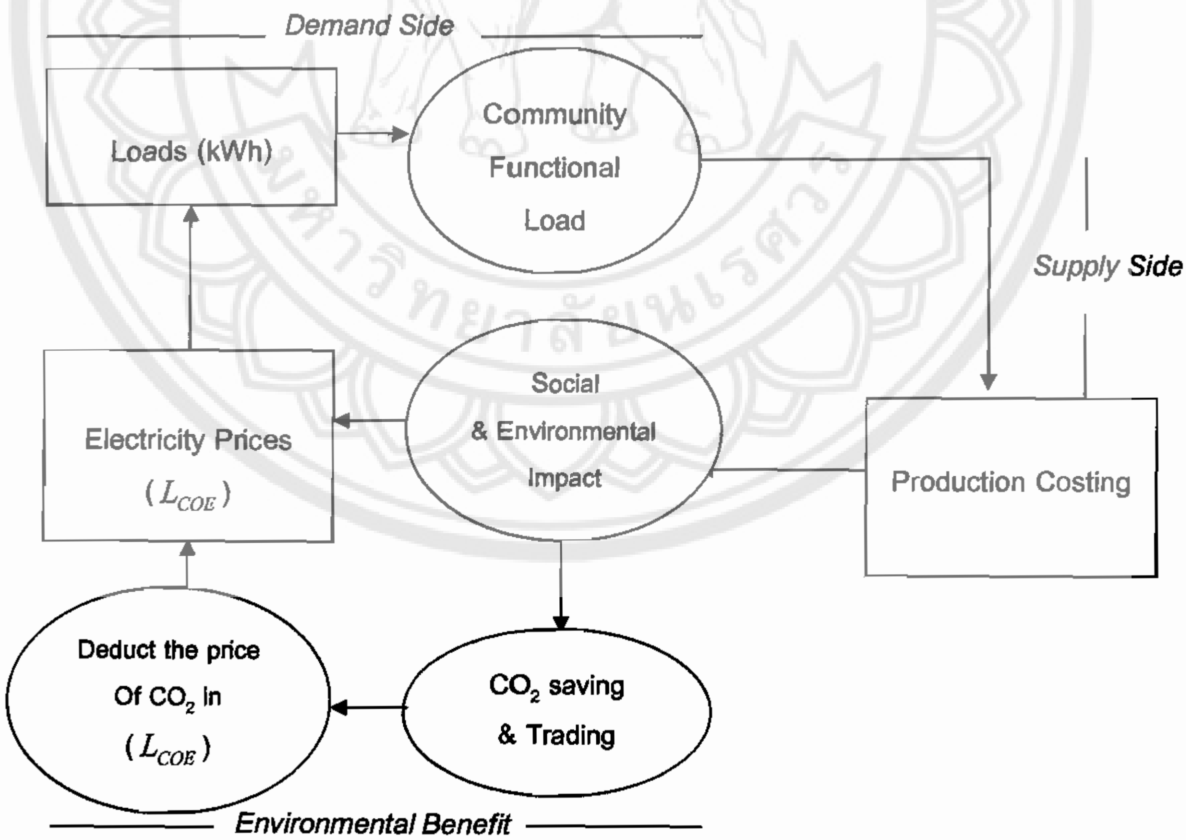

Figure 22 PV Rural Electrification Model (PRE-Model)

Based on site surveys and interviews about the users of PV system in many villages in Thailand, this model is being introduced for selecting the appropriate type of PV technology for different part of the rural areas with unique geographical as well as societal conditions. To initiate any PV project for rural electrification in Thailand, a study of basic load profile of society must be studied. Depending upon the type of society and culture behavior the communal functional load may vary for different rural community which must be considered and study well before kicking of any project and do system sizing, and calculation energy costing. The higher cost of energy production by PV doesn't make any project unviable. Social and environmental benefits that a PV rural electrification system can give also are to be taken as major contributions to society as well as whole country. The amount of CO_2 saved by the PV system could be a good model project for contributing Thailand's CDM ratification. Amount of carbon CO_2 saved can sell into carbon fixing market in the world which could contribute reduction of life cycle cost of electricity produced by any PV project. So in a broader sense, the life cycle cost of electricity produced by PV rural electrification project should be evaluated using the PRE model.

4.4.1 Economic Evaluation of Different type of PV system under taken for this study work

Based on same load profile, different PV systems such as SHS, BCS and CMG are considered for economic evaluation and cross comparison was carried out with Diesel Generator system for rural electrification. All economic parameters undertaken for calculation are same for all the systems. Figure 23 illustrates the different costs associated with different types of PV system as well and diesel generator system.

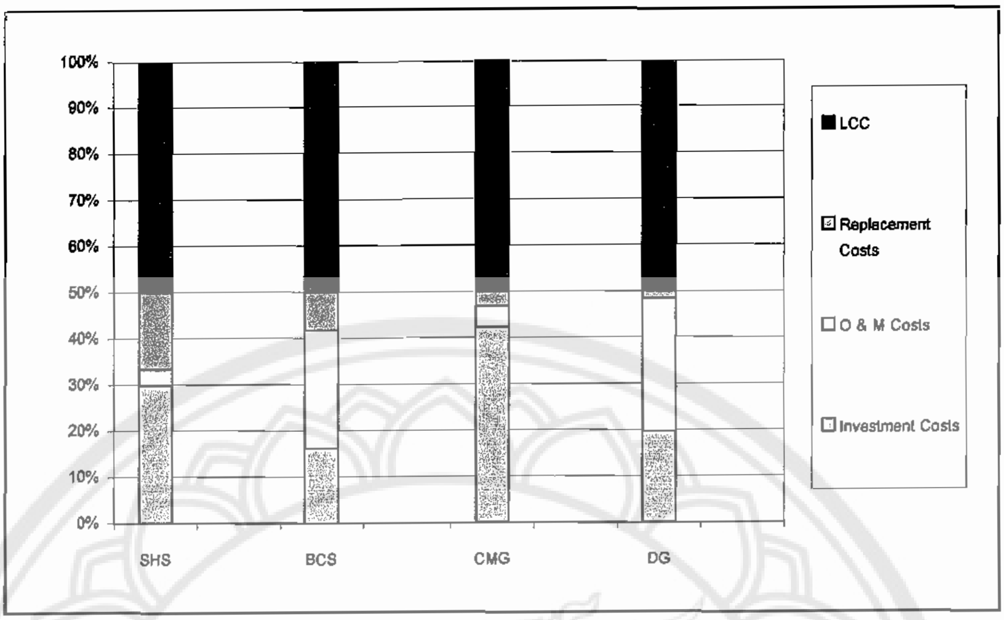

Figure 23 Different Costs Associated with PV and Diesel Generator system.

From the figure it can be concluded that operation and maintenance cost of SHS is the lowest while diesel generator system has the highest operation and maintenance cost.

The cost of replacing some of the system components also involves an additional 5% of the component cost as labor expenses (estimated). Figure 24 illustrates the life cycle cost of different PV system compared with diesel generator system.

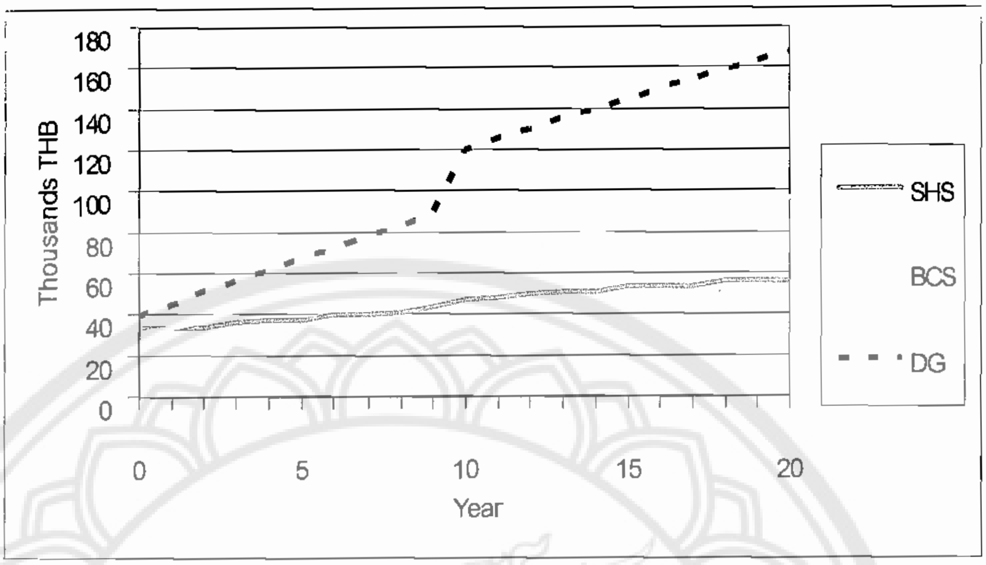

Figure 24 Life Cycle Cost of PV systems compare with DG

The results of LCC calculation for SHS, BCS, CMG and DGS were found to be THB 56,476, 69,989, 861,627 and 167,321 respectively. The Life Cycle Unit Energy Costs for each of the system were found to be THB 26, 45, 57 and 11 for each of the system respectively. The unit cost of diesel generator system seems to be the cheapest one but still environmental concerns should also be considered.

Detailed tabulated calculation of the LCC for all SHS, BCS, CMG and DG systems are shown in Annex.

The cost of electricity generated by diesel generator was found to be the lowest, but still another social as well as environmental consequences that might be caused by diesel generator and reliability of fuel supply in remote areas should be given due consideration. From the study SHS systems were found to be more suitable for scattered rural household electrification. As SHS systems are individual user dependent and if one user miss uses the system, it doesn't affect the other SHS in the community.

Figure 25 illustrates the transition on life cycle cost of unit energy produced by each of the system under study with the effect of number of house holds in the community. Similarly, figure 26 illustrates the percentage of each L_{COE} contributed by different categories of rural electricity supply system affected varying number of house holds in rural communities. As can be seen from the chart that the L_{COE} of SHS remains almost constant regardless of the number of house holds in a community. For the community more than 50 household the L_{COE} of CMG or DG have affects from number of house holds in the community. But still, scatter ness of settlement still to be considered.

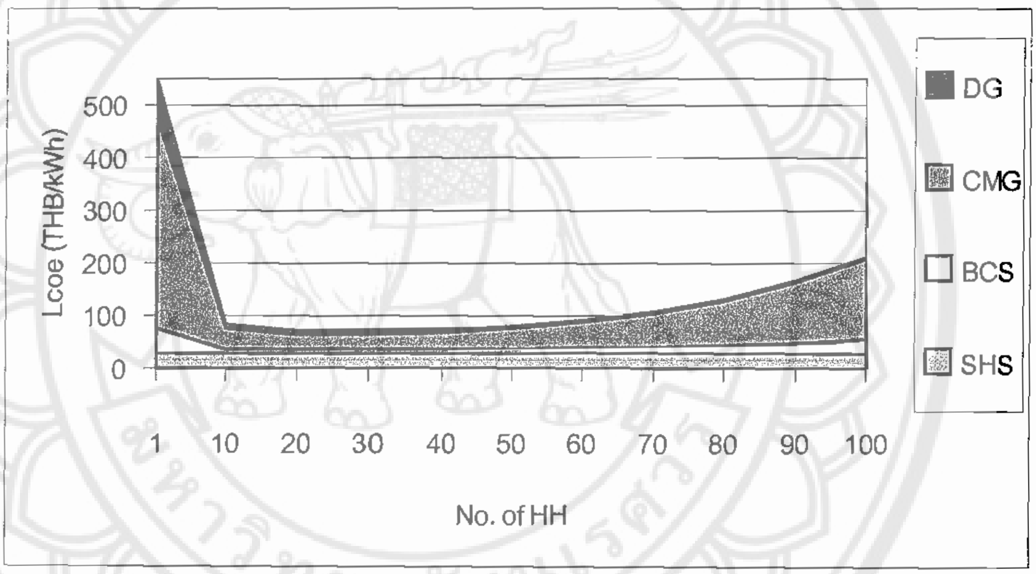

Figure 25 Area chart in L_{COE} of rural electricity supply system

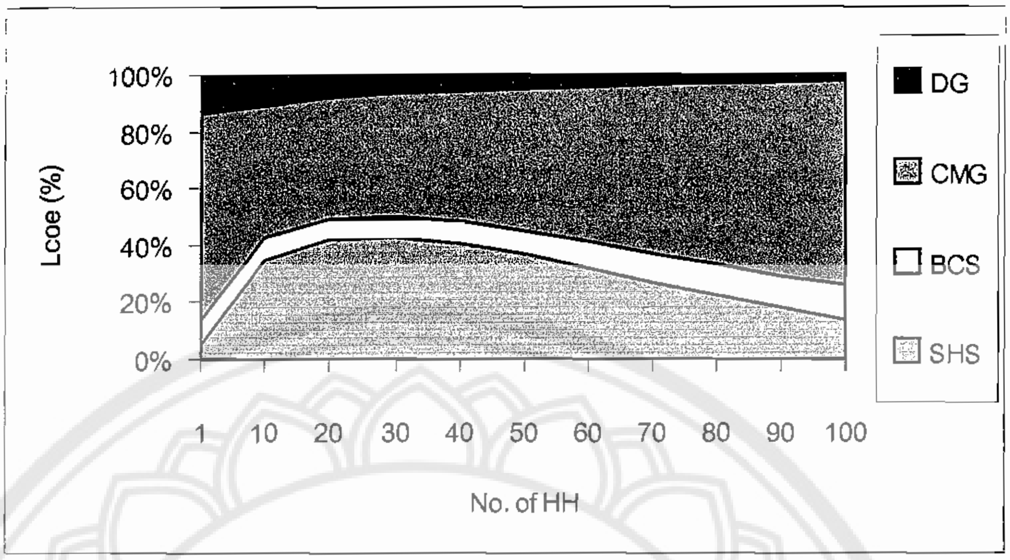

Figure 26 The trend of the percentage of each L_{COE} contributed by different categories of rural electricity supply system with respect of No of HH in the community.

Centralized Mini-Grid system might not be a suitable for widely scattered settlement of the rural people because of the cost of mini-grid extension. Though min-grid system well designed with protection system, miss using of load or miss handling of electrical appliances by one user would make whole system down putting whole community in out of electricity services.

Even though, battery charging stations are widely disseminated in rural electrification in Thailand, it is not very practical to carry heavy battery to distantly located charging station and carry back home. Frequent connecting and disconnecting of battery from the system might cause loose connection casing sparks good enough to cause a unwanted fire. While carrying to charging station and back to home, spill over of acid could case damages to skin or fabrics. Frequent moving of the battery can also reduce the battery life hence adding extra burden of cost to user.

4.4.1 Environmental benefits of Using PV by saving the CO2 Emission from Fossil Fuel

Use of renewable energy system for rural electrification saves use of fossil fuels for lighting purpose. Based on assumption and calculation made in Section 3.8 for fuel oil savings, it was found that annual kerosene of 16.8 litres / HH can be saved. Similarly, in case of diesel, annually 109.9294 litres / HH of diesel use can be saved. By saving the use of fossil fuel about 20,416.8 kg of over the life cycle of the SHS per household (at 2005 CO_2 emission rates). Therefore, combining the two CO_2 savings, the total estimated annual avoided CO_2 emission found to be 1,300.39 kg of CO_2 per year (for kerosene) and 1,305.27 kg of CO_2 per year (for diesel). This will be a small, but meaningful contribution towards Thailand's Clean Development Mechanism (CDM) and an addition to its Carbon Emission Reduction credit.