Economic Evaluation of Photovoltaic Systems for Rural Electrification in Thailand

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ABSTRACT

This paper presents successful story of rural electrification in Thailand. Ninety nine percent of the country is electrified, but the power supply mainly relies on conventional energy sources. The remaining one percent of unelectrified areas presents challenges as well as opportunities for renewable energy resources, especially for Photovoltaic applications. Photovoltaic systems for electrification may not always be economically viable, but it could provide a very valuable service to people in remote unelectrified areas with no hope for grid connection in the medium and long term. To satisfy the growing demand of energy in a community, a Photovoltaic 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. Without the interest and willingness of the community any community electricity system may fail in short span of time. 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 future worth benefit will be increasing as the value of money is decreasing because of inflation and the decreasing discount rate. Better health of the rural people will increase the involvement of the communities to more efficient economic activities, hence reducing poverty and increasing more economic mutual benefits in the community. This will increase the economic prosperity of the community.

Keywords : *Rural electrification, Photovoltaic systems.*

1. INTRODUCTION

Thailand is a developing country that is often cited for its success story of on-grid electrification. This success of on-grid electrification is mostly due to the Thai government's commitment to provide electricity to every Thai citizen. In 1971, the government began a huge initiative to provide electricity in rural areas, mostly through grid extension, but also through some off-grid Photovoltaic projects, such as solar battery charging stations. In 1974, the estimated percentage of electrified villages was 20%. By 2002, 99% of the households in Thailand were electrified. The estimated number of un-electrified households in Thailand in 2002 was about 440,716. It is widely believed that Photovoltaic technology will be useful in electrifying these remaining remote villages.

As mentioned above, Photovoltaic technology has been widely used by the government of Thailand since the late 70's for electrification. In 1994, nearly all (90%) of the 2.5 MW_p Photovoltaic installed were through state funded Photovoltaic projects. Thailand Solar Battery Charging Station (SBCS) programs represent nearly 40% of all Photovoltaic applications in Thailand. Other uses of Photovoltaic (PV) have been for water pumping in the northeast and, more recently, solar home systems in many parts of the country. Currently, the government estimates that there is a total capacity of 24 MW_p of PV systems installed in Thailand with more than 5,000 MW of the potential. [1]

Because of the central role of the government in funding, the commercial market development for PV in Thailand has been very slow. There are some private institutions, research institutes, companies, and organizations in Thailand that are active in R&D, dissemination, and demonstration of solar energy technologies, such as the School for Renewable Energy Technology in Phitsanulok. It is envisioned that the initiative to completely electrify Thailand with the use of SHS technology will open up the commercial market for PV systems.

Table 1 Status of Solar PV Applications in Thailand

Agency	**Total Installed (kW_p)**
Department for Alternative Energy and Efficiency (DEDE)	2,036.356
Public Works Department (PWD)	1,634.853
Provincial Electricity Authority (PEA)	18,147.990
Electricity Generating Authority of Thailand (EGAT)	786.464
Metropolitan Electricity Authority (MEA)	520.030
School of Renewable Energy Technology (SERT)	12.913
Remote Sensing Stations	16.800
Department for Marine Transport	4.160
King Mongkut's Institute of Technology, Thonburi (KMITT)	56.100
R & D of Department of Joint Logistics	360.00
The Ministry of Science, Technology and Environment (MOSTE)	1.640
Federation of Thai Industries (FTI)	42.000
Telephone Organizations of Thailand (TOT)	1,002.522
Energy Institute of Kasetsart University	2.700
Science Faculty of Taksin University	0.030
TOTAL	24,624.558

The Grid-based rural electrification program in Thailand is considered a success story. Decentralized electricity needs were restricted to isolated communities, where village cooperatives tend to own their generating facilities with support from the Department of Pubic Works and the Department of Alternative Energy Development and Efficiency (DEDE). The major organization governing electricity generation and supply is the Electricity Generating Authority of Thailand (EGAT). To classify the generation of electrical energy by type of fuel in the year 2005 of EGAT, most of IPP and SPP are from Natural Gas, Lignite, which generated 48,331 GWh, 30,386 GWh, 16,799.2 GWh and 12,372 GWh of electricity accounting 39%, 24%, 13% and 10%, respectively.

Grid extension alone does not ensure that all 99% of electrified households will have the ability to access electricity. Thus, the government planned a rural electrification development for grid extension accessibility; in the means time, they are facing obstacles of high investment and social constraints. The remaining 1% of households presents challenge as well as an opportunity for the use of renewable energy; especially photovoltaics (PV). Traditional electricity, even with all its success, has failed to reach unelectrified people and its key technologies face financial and environmental problems that may become insuperable. The traditional electricity supply may be unsustainable in remote areas where population density is very low and far from the central grid.

In Thailand, types of PV systems, which are used for electrification are currently being used are categorized into; central PV power plants for rural areas and roof–top grid connected PV systems for urban households – are not economically viable based on current economic conditions. Solar home systems are comparable in cost with grid extension. The potential of these systems are significant as it has potential of about 10 MW_p for solar home systems and 64 – 640 MW_p for roof-top grid – connected PV systems. But any program to disseminate these systems in Thailand at present has to be subsidized. At present, the government is supporting the PV industry through the large scale programs being implemented by Provincial Electricity Authority (PEA), Department of

Alternative Energy Development and Efficiency (DEDE), Electricity Generating Authority of Thailand (EGAT) and other government agencies.

2. ELECTRICITY PRODUCTION IN THAILAND

IPP (Independent Power Producer)

IPPs are the groups of power producers selected in a public. Seven producers were divided into two groups based on the commencement period of each project. The first three IPPs in Stage 1, started their operations in 2003. Among the remaining four IPPs in Stage II, an IPP started its operation as of June 2004.

SPP (Small Power Producer)

There are several regulations on the electricity generation processes to meet the qualifications as an SPP. The major characteristics of qualifying facilities are: a) using non-conventional energy such as wind, solar and mini-hydro, etc., b) using waste, residues or garbage from agricultural or industrial processes as fuels and c) electricity generation by co-generation. As of April 2004, 41 SPP contracts have been concluded and 2,116,900 kWh of electricity have been supplied by SPPs.

SPPs and IPPs Cogeneration Plants

Total electricity generated from SPP cogeneration plants in 2002 was 12,566 GWh, an increase of 4.9% over the previous year, and accounted for 11.5% of the national grid generation.

The total power production of 26,431 MW, is shared by EGAT 15,795 MW (60%), IPP 8,000 MW (30%), SPP 1,996 MW (8%), and import 640 MW (2%).

Electricity Tariff Structure

Thailand has a policy of uniform tariffs which involves cross-subsidization. This requires EGAT to sell electricity at a lower tariff to PEA as compared to Metropolitan Electricity Authority (MEA), irrespective of whether the cost of supply to PEA is higher than that of MEA. This implies that customers in the metropolitan areas basically subsidize the tariff of the provincial customers, and large users subsidize the smaller consumers. EGAT sells power to MEA and PEA at Bulk Supply Tariff (BST), the price of which depends upon the voltage, time of the day and day of the week. [2] Currently the average electricity sales price by EGAT under their BST structure is shown in Table 2 below:

Table 2 EGAT's Average Electricity Sales Price [3]

Customer	Price [Baht/kWh] 2004	2003
MEA	2.30	2.02
PEA	2.06	2.12
Direct Customers	2.14	2.04
Standby power supply	4.49	3.85
Other customers	1.75	1.75

The difference in the prices lies in the fact that PEA is compensated for its relatively high operating costs. The uniform retail tariffs for residential and small consumers used by MEA and PEA are shown in Table 3 below. It should be noted that the figures in Table 3 are for nominal (base case) values and do not include time of day or day of the week, as well as value added tax and service charge.

This tariff is subject to an Automatic Adjustment Mechanism which gives the companies the right to adjust their tariffs in order to cope with market fluctuations, especially changes in the price of fuel or other energy purchases, variations between actual and forecast inflation values used in determining operating costs.

Table 3 Retail Tariff Structure [4]

Customer Category	Tariffs (Baht/kWh)
Residential	
Less than 150 kWh/month	
First 5 kWh (1^{st} – 5^{th})	0
10 kWh (6^{th} – 15^{th})	1.3576
Next 10 kWh (16^{th} – 25^{th})	1.5445
Next 10 kWh (26^{th} – 35^{th})	1.7968
Next 65 kWh (36^{th} – 100^{th})	2.18
Next 20 kWh (101^{st} – 120^{th})	2.2734
More than 150 kWh/month	
First 150 kWh (1^{st} – 150^{th})	1.8047
Next 163 kWh (151^{st} – 313^{th})	2.7781
Small General Services	
- Low voltage	
First 150 KWh. (0 – 150^{th})	1.8047
Next 250 KWh. (151^{st} – 400^{th})	2.7781
> 400 KWh. (401^{st} - up)	2.9780
- Medium voltage	2.4649

3. PROBLEMS ENCOUNTERED WITH THE THAI GOVERNMENT'S APPROACH TO PV

While the Thai government's commitment to researching, developing, and implementing the use of solar energy technologies are commendable, there are still some problems with the approach that it has taken. First, with so many agencies and programs that have been mandated for solar energy research and dissemination, it is difficult to get a clear picture of exactly what the status of solar energy technology is in Thailand, how it is being used, and how successfully it has been used. Documentation and follow up solar technology projects in rural areas have, in some cases, been quite poor, and the lack of maintenance after installation with some of the projects have led to lower customer satisfaction with PV systems. The PV systems in Thailand also could benefit more by better coordination between the agencies with more cooperation among them. In the long term, the government of Thailand should consider another streamlining of agencies to further simplify the system and clarify each agency's mandates. This will improve the overall administration of all the solar energy research, development, and dissemination of the projects in Thailand. Another main problem is that power is very much centralized in Bangkok, and rural offices may not have the funding or manpower that is necessary for successful implementation of a solar project. By decentralizing power of control many of the projects to make them more adaptable and responsive to local needs, while still ensuring that they are accountable to a main agency in Bangkok would be an improvement. The Royal Thai Government should also consider that a large market for commercial solar energy technology could exist if it were not for the fact that heavy subsidies and state intervention have demolished the market for this technology.

4. RENEWABLE ENERGY DEVELOPMENT TARGET

The Thai government's ambitious energy strategy was launched with a target to increase energy production by renewable energy resources from 0.5 percent of total energy consumption in 2002 to 8 percent in 2011, excluding traditional energy from wood and charcoal. The share of renewable energy production, 8 percent, is equal to 6,540 ktoe. This production of energy consists of electricity at 1,060 ktoe, heat at 3,910 ktoe and bio-fuel at 1,570 ktoe.

All the forms of Energy production by the year 2011 are classified as follows:

1. Electricity

The production of electricity by renewable energy sources is targeted to be 1,060 ktoe, equivalent to 2,400 MW in 2011, including 560 MW of the power produced by SPP at present. The target plans to produce 250 MW by solar, 100 MW by wind, 350 MW by hydro, 1,020 MW by biomass, 100 MW by municipal solid waste and 20 MW by Biogas.

2. Heat

The renewable energy development targets to produce heat energy of 3,910 ktoe by 2011, which includes 5 ktoe from solar and the rest is from biomass, such as wood and agricultural waste; biogas from animal dung, waste water and solid waste.

3. Bio-Fuel

In 2011, the production of bio-fuel is targeted to reach about 1,570 ktoe, which includes 3 million liters per day of ethanol equivalent to 815 ktoe. The work plan is divided into two phases;

In the first phase, in 2004-2006, the use of ethanol will be promoted to substitute Methyl Tertiary Butyl Ether (MTBE) in Benzene 95 with a mixing ratio of 10 percent. It is expected that the production and consumption of ethanol will be 1 million liters per day by the year 2006.

In the second phase, during 2007-2011, ethanol will be used for replacing MTBE in Benzene 95 and 91, with the production and consumption of 3 million liters per day in 2011.

Bio-diesel consumption is targeted to be 2.4 million liters per day in 2011, which is equal to 755 ktoe, with a mixing ratio of 2 percent with diesel. The application of this mixed diesel will be for vehicle fuel and fuel for agricultural machines (tractors), as well as small and big scale factories.

The government has the following strategies for accomplishing the target of 8% energy production by renewable energy:

1. Renewable Energy Portfolio Standard (RPS)

The Government has launched a regulation for fossil fuel-powered electricity producers, making it mandatory to produce 5% of their total electricity production by using renewable energy sources. By 2011, the electricity produced by RE categories is expected to be: solar 200 MW, wind 100 MW, biomass 100 MW and solid waste 100 MW. Hence, there will be production and consumption of 500MW electricity by 2011by renewable energy.

2. Incentive**s**

The government intends to encourage and support investors to invest in renewable energy sources by providing low interest rates, subsidies, tax incentives, etc. With this strategy, the Government aims to have RE electrical power plants to generate a total of 1,440 MW by the year 2011, consisting of solar 50 MW, wind 350 MW, Biomass 740 MW and SPP 300 MW.

3. Research and Development on RE

The R&D on RE will be supported by the government in the areas of production and application of agriculture waste, waste water, animal dung, garbage, bio-diesel, ethanol, hydro, wind and solar. It will also offer support to research institutes and the private sector to cooperate on R&D for pilot projects, demonstration, production and applications of RE which have a high ratio of technological usage in the country.

5. NATIONAL POLICY

In Thailand, the principle national policies are provided in the National Economic and Social Development Plan (NESDP). The 9th NESDP (2002-2006) focused on natural resources, environmental management and science and technology strengthening strategies to:

- Promote the conservation and efficient and economical use of energy
- Support research on modifying and improving existing technologies in the energy sector
- Conserve and develop energy
- Promote the efficient use of energy in balance with the country's environment and natural resources
- Reduce dependency of energy sources from foreign countries

The energy policy of Thailand stresses on providing sufficient energy resources with reasonable prices, achieving economic and social development which enhances the competitiveness of the country.

6. ECONOMIC IMPACT OF RURAL ELECTRIFICATION

Rural electrification has economic effects on 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 Asian Development Bank notes that there are many other factors besides electrification that needs to be present in order to the village economic development projects to truly take-off, and electrification is "not even an important one at that." These factors include a stable market, reliable and cost effective transportation, availability of capital, skilled labor, raw materials, facilities, commitment from the community, and energy resource. Therefore 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.

7. FUTURE OF PHOTOVOLATIC 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.

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.

8. EVALUATION OF PHOTOVOLTAIC SYSTEMS FOR RURAL ELECTRIFICATION IN THAILAND

Technology

PV is already competitive for some small applications like lighting, television and water pumping etc. in remote areas. During the next few years, PV will be more acceptable in those remote communities which cannot be served by the Rural Electrification Program. In addition, Photovoltaics for electrification may not always be economically viable, but it could provide a very valuable service to people in remote unelectrified areas with no hope for grid connection in the medium and long term. The progress of these areas would ultimately contribute to the continued development of the country.

For selecting the suitable PV technology for rural electrification, many factors need to be considered such as type of system, load demands, operations and maintenance, and attitude of the rural community where such a system is to be installed. Although, a solar home system is considered a very suitable decentralized rural electrification technology, studies show that it is not suitable in long term as demand for electricity grows as the living standard of the communities increase, unless the households are ready to pay for increasing the capacity of the SHS.

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 decentralised 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.

Social Impacts

The Thai Government's 9th National Economic and Social Development Plan (NESDP) has emphasised 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.

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.

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. Figure 1 shows the future worth benefit increases while the value of money decreases because of inflation and the discount rate. 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.

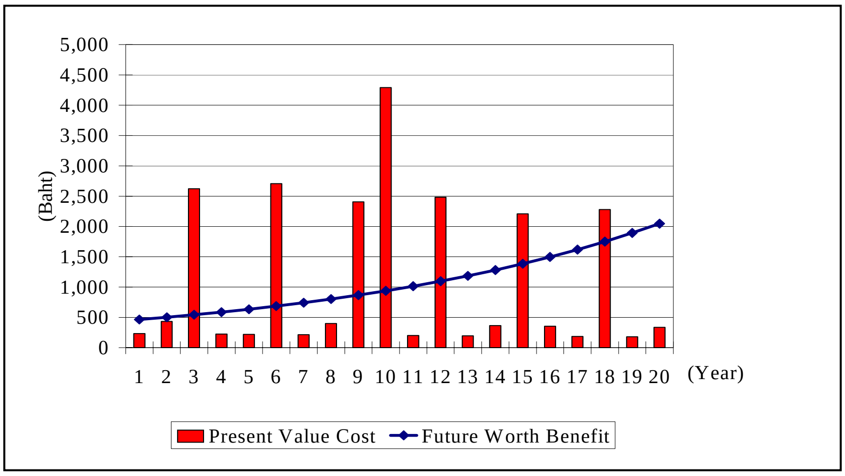

Fig. 1 Correlation between Present Value Cost and Future Worth Benefit of SHS.

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 4:

Table 4 Study of Investment Trend in the Establishment of Solar PV Industries in Thailand [5]

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				

9. CONCLUSION

Certain guidelines must be strictly followed to make any PV system application successful for rural electrification. The load pattern of the community must be studied very well and a technology or a system must be chosen that suits the best as per the load profile of the community. A good introduction of the system has to be given to community so that they understand all the components of the system and will be familiar with functionality of the system. The selected system should be acceptable to the communities; otherwise, their willingness to maintain the system will decrease with the passing of the time. If an acceptable system is being selected for the remote community electrification, the community will be willing to co-invest and pay for maintenance of the system that makes system sustainable and longer life. The owner and operators of the system must be trained well about the operation and maintenance of the system. This will make system self-sustainable within the community, and a local authority should be able to monitor and evaluate system efficiency of the selected system. Once the community feels that the system belongs to themselves as their property, they will benefit from this property because of the sustainable life of the system and more economic activities among the community people. The investment made on PV, therefore, will benefit future generations by making them familiar with the system for their comfortable lives.

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