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Developing a Method to Accurately Estimate the Electricity Cost of Grid-Connected Solar PV in Bangkok

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Abstract-- **Solar photovoltaic electricity is more expensive compared with conventional electricity at retail level. As a result, general public members do not find the solar PV electricity an attractive option to use for generating a portion of their electricity need. To promote PV electricity utilization and to make it more attractive, Governments of some countries like Germany, Japan, USA, Australia, and etc. have introduced solar PV incentive programs. Most of grid-connected photovoltaic (PV) systems on residential or commercial buildings in these countries are installed by individuals interested in generating part of their electricity emission-free. For some of these people the economics of the PV electricity is likely to be of secondary importance, while majority of them would like to see financial return to become interested to use PV electricity. The objective of this paper is to present the results of a study conducted on the economic aspects of solar PV to estimate the electricity price of grid-connected rooftop PV system under climate conditions and geographical location of Bangkok (at the latitude of 13.5^o N, and longitude of 100.5^o E), to see if the use of PV electricity is attractive and affordable by residential customers. The results of this study will help to determining an appropriate feed-in tariff for solar PV electricity in Bangkok.**

Keywords- economic aspect; electricity; solar photovoltaic

I. INTRODUCTION

Worldwide, power sector provides 18,000 terawatt-hours of electric energy every year, around 40% of world's total energy use. In doing this it produces more than 10 giga-tonnes of carbon dioxide every year, the largest sector contribution of humanity's fossil-fuel derived emissions [1].

Obviously, the easiest way to cut the carbon released by electricity generation is to increase efficiency of electric appliances and electric systems. But there are limits to such gains, and there is the familiar paradox that greater energy efficiency can lead to greater energy consumption. Thus, the response to reduce emissions released by electricity generation and reduction of climate change must involve a move to de-carbonizing power sector and using carbon-free sources of electricity.

This requires serious thinking about the extensive use of new and renewable energy sources and technologies such as solar and wind.

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II. SOLAR ENERGY

Solar energy is a vast and largely untapped resource. The World Energy Council estimates the earth's surface, on average, has the potential to capture around 5.4 GJ (1.5 MWh) of solar energy every year. Solar energy accounted for 0.1% of the world's total primary energy consumption in 2007, although its use has increased significantly in recent years [2].

By end of 2012 the cumulative installed capacity of solar PV system exceeded 102000 MW in IEA member countries alone [8]. This was about 1400 MW at the end of 2000. This has been shown in Fig. 1. According to this figure, installation of solar PV system has been growing at an annual average of more than 25% since 2000.

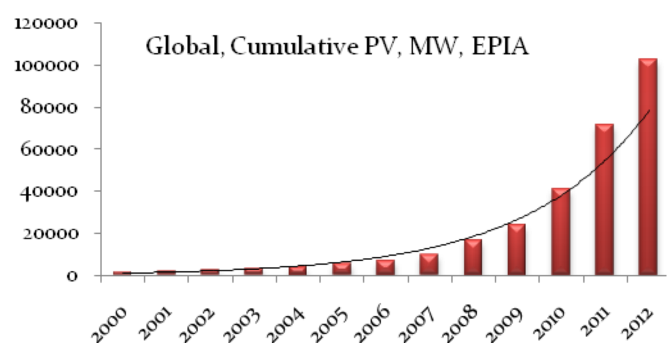

Fig. 1 Cumulative PV Capacity MW

Solar PV technology converts sunlight directly into electricity using photovoltaic phenomena. PV systems can be installed on rooftops, integrated into building designs, or scaled up to megawatt scale power plants. PV systems can also be used in conjunction with concentrating mirrors or lenses for large scale centralised power.

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The amount of solar energy incident on the world's land area far exceeds total world energy demand. Solar energy thus has the potential to make a major contribution to the world's energy needs. However, large scale solar energy production is currently limited by its high capital cost.

The cost issues related to solar energy has always been a major negative point for solar energy in general and solar photovoltaic in particular. Increasing manufacturing capacity has led to remarkable reduction in cost of solar PV electricity, but the PV electricity production cost is still far above the electricity price from conventional energy technologies.

This price difference is very high particularly in those countries, where price of electricity from conventional power plants is relatively low. Government policies investment costs and risks are projected to be the main factors underpinning future growth in world solar energy use [2].

Solar energy, although expensive but it has the potential to play a crucial role in the world's energy supply, now and in the future. The last five years has been a period when PV energy changed from being a small-scale contributor to energy supply to being a more substantial one, and the next five years look like being a period when the technology could have an even more substantial impact.

Cost calculations show that even in sunniest place it is impossible for PV to be able to compete with conventional electricity without reasonable government subsidies or reasonable fee-in tariff.

Solar radiation is intermittent because of daily and seasonal variations. However, the correlation between solar radiation and daytime peak electricity demand means that solar energy has the potential to provide electricity during peak demand times. Photovoltaic systems are well suited to off-grid electricity generation applications, and where costs of electricity generation from other sources are high (such as in remote communities). Relatively high capital costs and risks remain the primary limitation to more widespread use of solar energy. Government climate change policies, and research, development and demonstration (RD&D) by both the public and private sectors will be critical in the future commercialisation of large scale solar energy systems for electricity generation.

III. Solar Exposure in Bangkok

The potential for using solar energy at a given location depends largely on the solar radiation, the proximity to electricity load centres, and the availability of suitable sites. The annual solar resource varies considerably around the world. These variations depend on several factors, including proximity to the equator, cloud cover, and other atmospheric effects.

The amount of solar power available per unit area, which is known as irradiance or radiant flux density, varies with latitude, longitude, elevation and season of the year in addition to time in a particular day. Sun radiation data used in this study are the data valid for latitude and longitude of Bangkok. Latitude of Bangkok is 13.5^o N, and longitude of Bangkok is 100.5^o E. This has been shown in Fig. 2.

The amount of sun radiation received in Bangkok is between 16.56 MJ/m^2 in August to 21.89 MJ/m^2 in March with the annual average of 18.94 MJ/m^2 [3]. This has been shown in the Table I.

It is important to mention that unlike high latitude regions the seasonal sunlight hour changes are not significant. This means, Bangkok receives the sun radiation relatively uniform throughout the whole year.

Fig. 2 Map of Thailand

TABLE I

MONTHLY AVERAGED RADIATION INCIDENT ON AN EQUATOR-POINTED

4.75	4.6	4.69	4.64	5.16	5.46	5.26

TILTED SURFACE (KWH/M2/DAY) OF BANGKOK

Tilt:13^o	Jan	Feb	Mar	Apr	May	Jun
kWh/m^2	5.63	5.99	6.08	6.03	5.28	4.88
MJ/m^2	20.27	21.56	21.89	21.71	19.01	17.57
Jul	Aug	Sep	Oct	Nov	Dec	Ave.
17.10	16.56	16.88	16.70	18.58	19.66	18.94

IV. Solar PV Production Estimation

The sun data for Bangkok, which were provided by NASA, give the average daily solar exposure for each month and the year. Typical values for daily global solar exposure range between 16 MJ/m^2 and 22 MJ/m^2 (mega-joules per square meter per day). For high latitudes of Bangkok, the values are usually highest in clear sun conditions during February, March, and April and lowest during August, September, and October. This has been shown in Fig. 3.

Cost calculation of grid-connected solar PV electricity in Bangkok as the main objective of this paper for the purpose of determining the actual production cost of PV electricity. The results of this calculation gives idea about what the reasonable feed-in tariff for Bangkok would be. These results have been presented in the Fig. 4-9 for different assumptions in installation cost. Fig. 4, 5, and 6 show the solar PV production cost for 3 different installation costs (for example) from $11,000, $14,000 and $17,000 installation cost for a 5 kW PV system for mortgage rate of 6%, while Fig. 7, 8, and 9 show the solar PV production costs for different installation costs $11,000, $14,000, and $17,000 for a 5 kW PV system for mortgage rate of 1%.

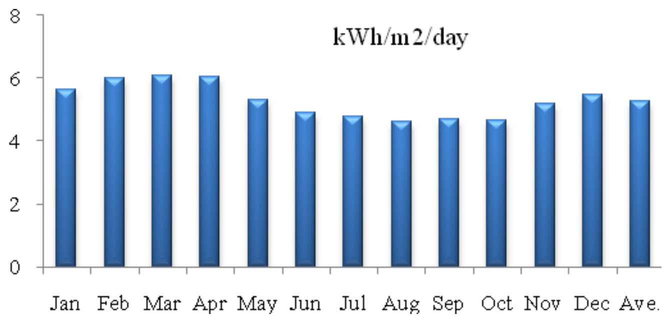

Fig. 3 Variations in daily solar energy availability

Time value of money has been considered in this study, assuming Inflation rate: 3%, Discount rate: 4%, Mortgage rate: 1% and 6% (it is assumed that fund to install PV system is borrowed from a bank).

Table II shows the information and data used to estimate the electricity production cost of solar PV in Bangkok for different capital upfront costs.

As solar PV power generation is investment capital intensive, so the mortgage rate, at which the money is borrowed from a financial institute, has significant effect on solar PV electricity production cost. For this reason simulation results show for 2 different mortgage rates namely 6% and 1%.

TABLE II
DATA USED TO ESTIMATE THE ELECTRICITY PRODUCTION COST OF SOLAR PV IN BANGKOK

Inflation rate	3
Discount rate	4
Mortgage rate	1 & 6
Size in kW	5
Life time (Year)	20
X factor	0.99
Pa Present worth factor for operation cost	18.27
Pa1 Present worth factor for maintenance	18.1
O&M($/kWh)	0.02
O&M($/System/year)	169.8
O&M for life time	3074
Performance ratio	0.85

Following figures (Fig. 4-6) are simulation results for the case of mortgage rate 6%.

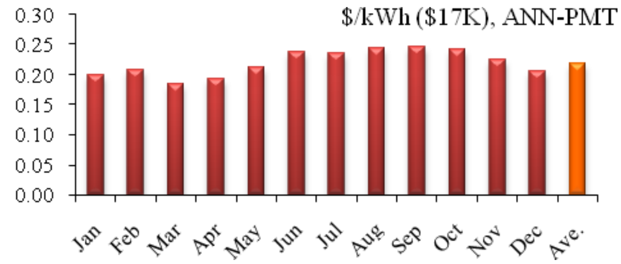

Fig. 4 PV Electricity cost, $17K, mortgage: 6%

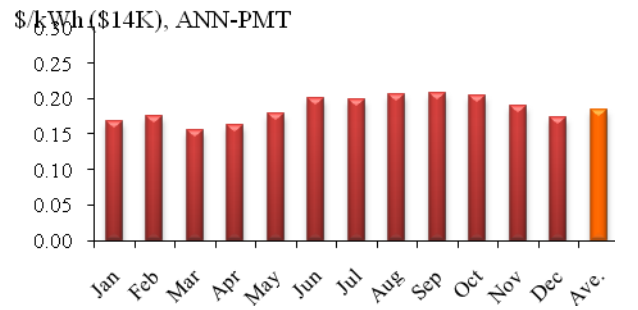

Fig. 5 PV Electricity cost, $14K, mortgage: 6%

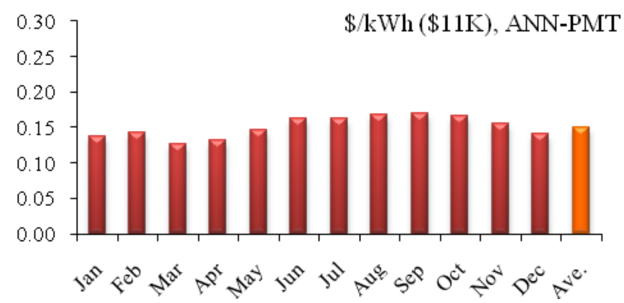

Fig. 6 PV Electricity cost, $11K, mortgage: 6%

Following Figures (Fig.s 7-9) are simulation results for the case of mortgage rate 1%.

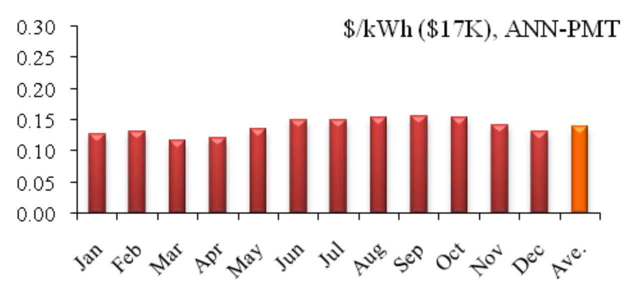

Fig. 7 PV Electricity cost, $17K, mortgage: 1%

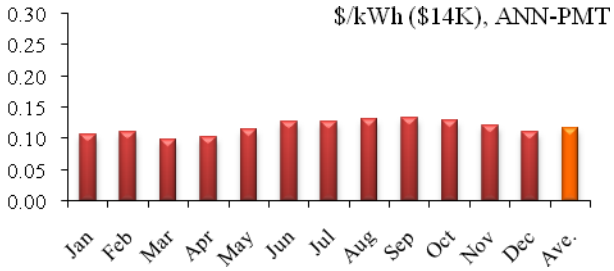

Fig. 8 PV Electricity cost, $14K, mortgage: 1%

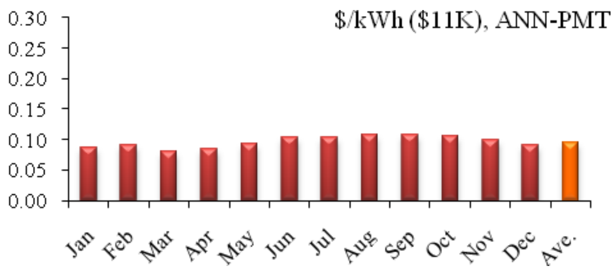

Fig. 9 PV Electricity cost, $11K, mortgage: 1%

Table III shows the annual average electricity production cost in $/kWh for rooftop PV systems installed in Bangkok. The figures shown in this Table are simulation results of a computer program developed by the author. In this simulation it has been assumed that the installed unit if a 5kW system and installation cost ranges from AD$10,000 to AD$17,000 depending on the quality of PV products.

TABLE III
ANNUAL AVERAGE SOLAR PV ELECTRICITY COST FOR DIFFERENT PV INSTALLATION COSTS

In $1000 / 5kW Peak	Mortgage: 1%	Mortgage: 6%
17.0	0.14	0.22
16.5	0.14	0.22
16.0	0.14	0.21
15.5	0.13	0.21
15.0	0.13	0.20
14.5	0.12	0.20
14.0	0.12	0.19
13.5	0.12	0.19
13.0	0.11	0.18
12.5	0.11	0.17
12.0	0.11	0.17
11.5	0.10	0.16
11.0	0.10	0.16
10.5	0.10	0.15
10.0	0.09	0.15

V. CONCLUSIONS

This paper has presented the results of a study conducted to estimate an accurate unit price of solar PV electricity ($/kWh) in Bangkok. The PV electricity prices obtained in this study are based on the location-dependent sun radiation data as well as country's economic factors. As one can see from the Fig. 4 to 9, the cost of PV electricity is most probably far above the conventional electricity price. In order to make solar PV utilization attractive to the public, the Thailand's Government needs to offer high incentive or to develop an attractive feed-in tariff to encourage house owners to come forward with interest of using rooftop solar PV systems. In conclusion, the government policy settings will continue to be an important factor in the solar energy market outlook. Research, development and demonstration by both the public and private sectors will be crucial in accelerating the development and commercialization of solar energy, especially large-scale solar power stations.

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VII. BIOGRAPHY

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