The analysis of the location potential appropriate for constructing the decentralized electricity plant from solar energy

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Abstract

Sufficient, flexible and reliable electricity supply that allows demand response plays a vital role in the economic development, as. Electrical power drop or outage may result in big economic losses. This is always a major concern with large fossil fuel based power plants. The world is also facing now environmental problems, such as climate change, caused by the use of fossil fuel-based power plants. On the other hand, decentralized renewable energy-based power plants, like solar PV power plants are now proving to be alternatives to fossil-fuel based power plants. Decentralized renewable energy power plants are now being installed in many places in Thailand, and they are showing that these systems can be reliable, flexible and secured energy supply. More of these systems can be installed in the country. This study aimed to propose a method for identifying and analysing potential locations of decentralized solar PV electricity plants. The method include the use of both the Geographic Information System (GIS) and the Analytic Hierarchy Process (AHP). A case study was conducted for Chiang Rai province. Using the two processes led to the creation of a map and concluding the information applied in a decision making of finding the appropriate and potential that shows location in Chiang Rai province where are the suitable locations. Locations were classified in terms of elevation levels and by districts of the province. The method is not difficult to apply and can readily be used by investment decision makers in both the government and private sectors.

Keywords:

Decentralize power plant, Renewable energy, Analytic Hierarchy Process, Geographic Information System.

1. Introduction

Electricity is a basic infrastructure as it powers and drives the economy. Thailand have had high economic growth rate and the country's economy is expected to continue growing. With this, power capital expenditure and electricity production growth rate have also been high. These require e high investment costs particularly for fossil fuel based power plants. There are also the negative environmental impacts. The total of electrical power consumption of Thailand in 2017 was 185,370 million kWh. The total power generation capacity of Thailand is was 34,101 MW; the highest power generation capacity of MEA, PEA and EGAT are 30,303 MW, while the total power generation capacity of Electricity Generating Authority System is 28,578 MW [1]. Owing to high electricity demand from both the housing and the various economic sectors, more electricity plants.

There are two types of the electricity generation plants; the large centralized plants, which are mostly fossil-fuel based, and the decentralized plants, most of which today, are getting to be renewable energy-based. The centralized fossil-based electricity generation plants have several negative environmental impacts on our planet, the most serious of which is global warming now leading to catastrophic climate change [2]. Fossil-based power plants have also high investment cost and take longer time to design and construct. Also, they can significantly reduce the electric supply if they suddenly stop operations, resulting to possible big economic losses. Meanwhile, decentralized electricity plants that t use renewable energy such as water, wind, solar, biogas and biomass. Generally have no or very minimal fuel costs. Because the capacities of these plants are smaller, investments are much lower and design and construction times are shorter. As a result, power outages from these plants do not have as much significant impact on the overall power supply, and impacts on the economy are much lower too. However, because renewable energy based decentralized electricity plants, particularly solar and wind, are intermittent, it will be good to have them be part of a smart micro-grid that include energy storage and digitized instrumentations to manage the transmission and distribution of electricity, as well as the demand for electricity.

As mentioned earlier, electricity generation from big fossil-based centralized power plants have serious negative environmental impacts. Building decentralized renewable energy-based power plants in distributed locations instead can significantly reduce these negative environmental impacts. There is need however that the locations of the renewable energy power plants, particularly solar, wind and biomass (for small hydro, site is defined the location of the stream), are properly identified. However, information needed for proper identification of sites are still mostly lacking and method for identification and analysis of potential sites are lacking. Thus, this research focuses on identifying and analysing potential locations for decentralized solar PV power plants using the Geographic Information System (GIS) and the method of weight value analysis using the Analytic Hierarchy Process (AHP), using locally available data. With these methods, a solar map is constructed showing locations suitable for constructing decentralized solar PV power plants. This research made this analytic information tool to be easy to apply and help both private and the government sectors in their investment decisions.

1.1. A case study in Chiang Rai Province

Chiang Rai Province was selected to apply the analytical tools for identifying and analyzing appropriate locations that has potential for constructing of decentralized solar PV electricity plants. Chiang Rai is located in the north most of Thailand (19°54'30.89"N, 99°49'57"E.), 859 kilometers far north of Bangkok. The province has an area of around 7,298,981 Rai or 11,678.369 square kilometers (1 Rai = 0.395 acre) [3].

Fig. 1 Map of area and location of Chiang Rai.

1.2. Geography

Chiang Rai is a mountainous area with elevations reaching to 1,500 – 2,000 meters above sea-level. The plains and valleys in the province central areas are about 410 – 580 meters above sea level. Lands are classified as follows; agricultural areas around 3,227,888 Rai or 44.22% of total provincial area, forests is around 3,015,096 Rai or 41.31%, and about 1,055,997 Rai or 14.47% are other areas (for residence, commerce, industry and government sectors) [4].

1.2. Climate

The climate in Chiang Rai is very cold in winter (October-February) and mildly hot in summer (March-May). The average temperature of the year is between 19.5 – 27.5 Celsius. Heavy rains occur during April to September. The average annual rain per year is around 1,800 Milliliters and the average humidity is about 77.83% [5].

1.3. Solar energy potential

The Solar radiation in Chiang Rai province was analyzed using world climate data. This showed that the highest solar radiation intensity was around 18,334.2 KJ/ m^2.day, the lowest intensity about 17,067.6 KJ/ m^2.day and the average intensity 17,700.9 KJ/m^2.day [6].

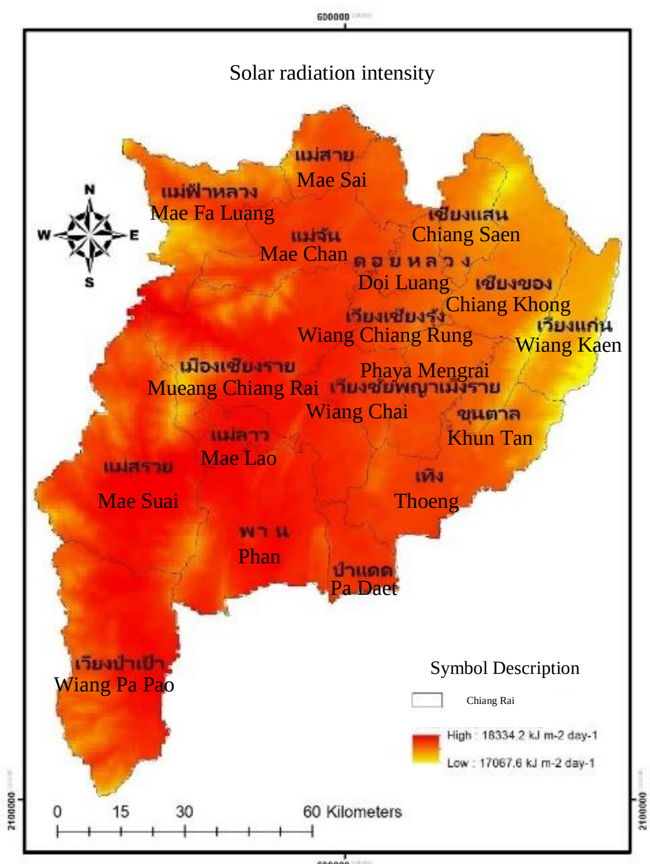

Fig. 2 Map showing the intensity of the sun light in Chiang Rai.

1.4. Research methodology

1. Determining the conditions for building e decentralized solar PV electricity plants by analyzing data via Geographic Information System. The sources of GIS data are shown in Table 1.

Table 1 Source of geographic information.

Data	Source
Solar Irradiation	World Clim Website [6]
Proximity	
- Transportation route	Department of Land Development 2559 [7]
- Transmission line	Department of Land Development 2559 [7]
Environment	Department of Land Development 2559 [7]
Land Use	Department of Land Development 2559 [7]

2. Collection of analytical information needed for the simulation model for the decision-making flow chart in the identification of appropriate locations for building decentralized solar PV electricity plants.

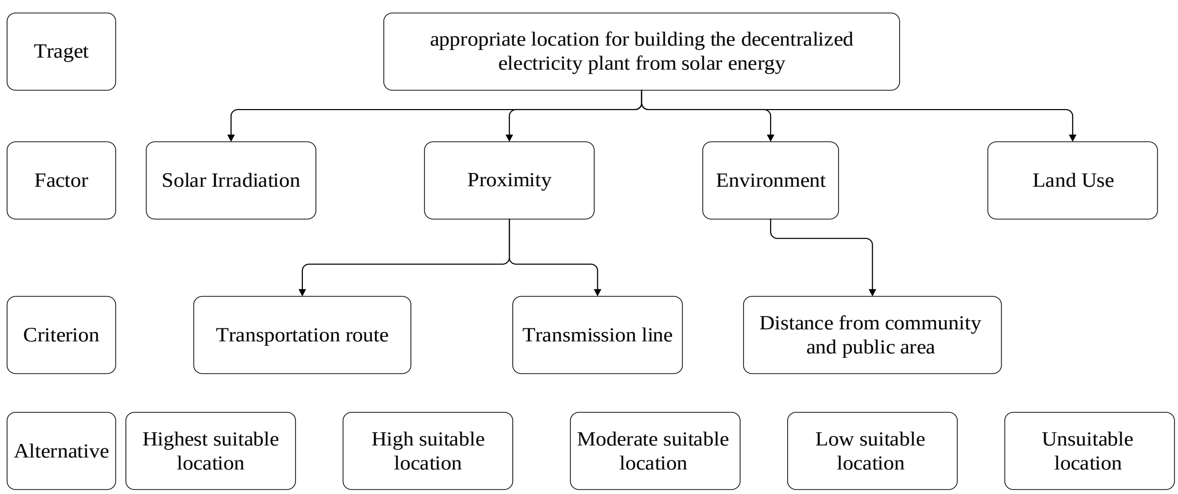

Fig. 3 Map of hierarchy chart of the decision making in seeking for the appropriate location for building the decentralized solar PV electricity plants.

3. Collection of information based on the decision making flow chart to compose a guide questionnaire for experts on how to weigh the factors and compare them using the Analytic Hierarchy Process (AHP). AHP compares the importance of each factor through a pairwise comparison using comparison scores shown in Table 2. The questionnaire consists of three parts: Part 1 - compare all factors, Part 2 – compare main and sub-main factors by considering the level of importance of factors by a pairwise comparison. The factor level on the left line compares with the right level in the same line; and, Part 3 – choose the rating score affecting the suitable location for building the decentralized solar PV electricity power plants in Chiang Rai province, by filling the score from 1-9 as shown in Table 2.

Table 2 The comparison of the important level of factors.

Important level	Meaning
1/9	Extreme
1/7	Very strong
1/5	Strong
1/3	Moderate
1	Equal
3	Moderate
5	Strong
7	Very strong
9	Extreme

4. The questionnaire was answered by nine experts in the field of energy; with three-from the government sector, three from the investors and three from the academics.

5. The weight of each factor was analyzed using AHP by considering the consistency ratio (CR). This was in order to check the comparison of weighing the importance of every criterion. It is at the acceptable level if CR < 0.10 which indicate a proportion value. If CR ⩾0.10, it shows that the proportion value is not consistent with each, other, and needs to be adjusted. Or the score on that factor can be given again, to calculate a value of C.R. ⩽ 0.1 and then the weight of factors can be applied.

6. Take all the total scores calculated from the total scores of all factors according to weighing value, and this will be the total suitability score "S" which is the rating for the appropriate locations [8] and is determined by the following equation.

$$S = \sum_{i=1}^{n}(W_i \bullet R_i) \quad (1)$$

S = Suitability
W_i = weight value of factor i
R_i = score value of factor i

7. Develop a rating scale for classifying the appropriate level of the location for building the electricity plant. This consists of five levels; highest suitable location, high suitable location, moderate suitable location, low suitable location and lowest suitable location, each of which has an equal interval range as an equation below.

$$R = \frac{H - L}{N} \quad (2)$$

R = Range
H = Highest rating – scale level
L = Lowest rating – scale level
N = Number of rating – scale levels

8. Overlaying of renewable energy potential maps – resource potential maps for solar energy, wind energy, and biogas (if all these renewable energy resource maps are available), and map of road and transmission lines, map of water sources, map on environment data and map of land utilization. Some areas are excluded such as community and public areas, government office areas and water and high mountain conservation areas etc.

2. Results and Discussion

2.1. Results of the analysis of the factor weight

The results of the analysis of the factor weight using AHP considering the consistency ratio (CR), shows that it is an acceptable value when CR is equal to 0.07 because of the factor consistency. Thus, the weight value can be applied in analyzing the appropriate location for an e electricity plant. It shows the factors having the most importance in locating solar energy electricity plants; Solar radiation (69%); followed by road and transmission line (18%); and, least important, environment (6%), as shown in Table 3.

Table 3 The comparison of factors in making a decision on the suitable location for solar PV electricity plants.

Factors	Solar Irradiation	Road and transmission line	Environment	Land utilization
Solar Irradiation	1	7	7	7
Road and transmission line	1/7	1	4	7
Environment	1/7	1/4	1	1
Land utilization	1/7	1/7	1/1	1
Total	4.429	9.393	13	16

Table 4 Importance of factors, by weight value, for analysing suitable locations for decentralized solar PV electricity plants.

Factors	Weight
Solar Irradiation	0.69
Nearness	0.18
Environment	0.06
Land utilization	0.07
CR value	0.07

Table 5 Weight and score value in analyzing the decentralized solar PV electricity plants by AHP.

Factor	Criteria	Factor weight	Criteria weight	Total Weight (W_i)	Rating (R_i)	Total Suitability Score (S)
1.Solar Irradiation	Range of Solar Irradiation (KJ/m^2.day)	0.69	1	0.69		
	<16,000				6	4.14
	16,000-17,000				6	4.14
	17,000-18,000				7	4.83
	18,000-19,000				7	4.83
	19,000-20,000				9	6.21
	>20,000				9	6.21
2.Nearness	Distance from transportation route (m)	0.18	0.11	0.02		
	< 500				9	0.18
	500 - 750				7	0.14
	750 - 1000				7	0.14
	> 1000				7	0.14
	Distance from transmission line (m)	0.18	0.89	0.16		
	< 100				9	1.44
	100 – 500				8	1.28
	500 – 1000				7	1.12
	> 1000				5	0.8
3. Environment	Distance from community and public area (m)	0.06	1	0.06		
	< 100				7	0.42
	100 – 500				7	0.42
	500 – 1000				9	0.54
	> 1000				9	0.54
4. Land utilization	Type of land utilization	0.07	1	0.07		
	Bare land				9	0.63
	Rice field or ranch				5	0.35
	Crop field				5	0.35
	Tree and fruit tree				5	0.35
Total		1		1		

2.2. Results on the analysis of suitable locations for solar PV electricity plants.

Determination of suitable locations for e decentralized solar PV electricity plants in Chiang Rai province depends on analyzing the total suitability score (*S*) as shown in Table 5. The overlaying is analyzed as follows.

1. Rating the suitable location for the decentralized solar PV electricity plants.

Table 6 The appropriate level of the location for decentralized solar PV electricity plants.

Rating scale of suitable location	Range of suitability score
Highest suitable location	7.62 – 7.46
High suitable location	7.45 – 7.23
Moderate suitable location	7.22 – 7.00
Low suitable location	6.99 – 6.77
Unsuitable location	6.76 – 6.54

From Table 6, the score range of the highest suitable location is between 7.46 - 7.62, the highest suitable location between 7.23 – 7.45, the moderate suitable location between 7.00 – 7.22, the low suitable location between 6.77 – 6.99 and the unsuitable location between 6.54 – 6.76.

2. Map showing the appropriate locations for the decentralized solar PV electricity plants

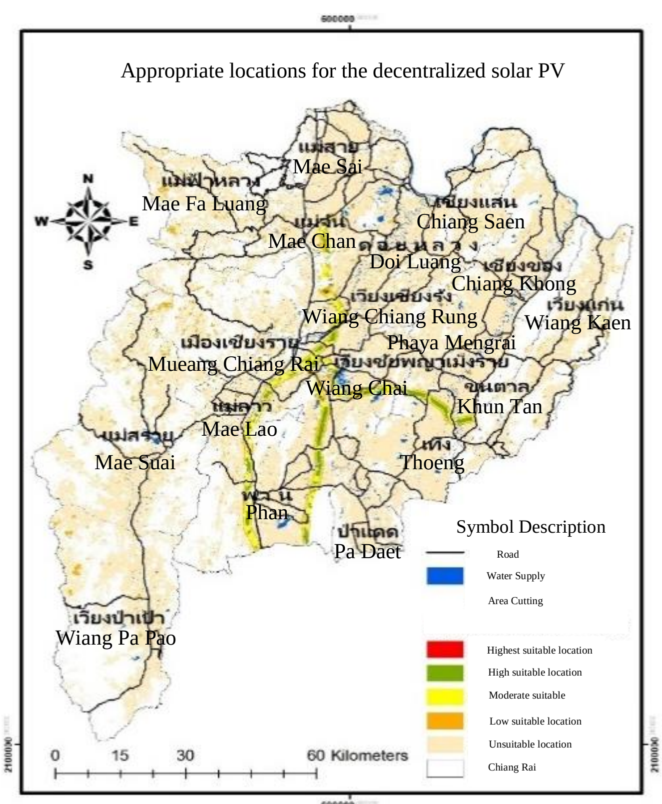

Fig. 4 Map showing the appropriate locations for decentralized solar PV electricity plants.

Fig. 4 shows the suitable location areas for decentralized solar PV electricity plants in Chiang Rai province are 4,040.17 Rai at the highest level, 46,055.96 Rai at high level and at 335,023.36 Rai low level.

3. The appropriate potential locations for e decentralized solar PV electricity plants. Solar energy.

Table 7 Results on the analysis of potential suitable locations for decentralized solar PV electricity plants.

Suitable location for decentralized solar PV electricity plants	Areas (Rai*)
Highest suitable location	4,040.17
High suitable location	46,055.96
Moderate suitable location	89,863.56
Low suitable location	335,023.36
Unsuitable location	4,137,631.96
Total area	4,612,615.01

*(1 Rai = 0.395 acre and 0.0016 square kilometers)

Table 7 shows the areas suitable for decentralized solar PV electricity plants in Chiang Rai are; 4,612,615.01 Rai in the highest e location, 4040.17 Rai, in high location, 46,055 Rai in moderate level location, and 89,863.56 Rai in and low level location 335,023.3; 4,137,631.96 Rai in unsuitable location. When locations are considered by district, the suitable areas in Chiang Rai province are shown on Table 8.

3. Conclusion

The analysis of potential suitable locations for solar PV electricity plants depends on four factors; Solar Irradiation, nearness to the road and the electricity transmission line, environment and land utilization. These factors are classified into main and sub-main factors through AHP. Then, the scores for the factors are calculated to determine mathematical mean score. The mean score is calculated and are ranked according to the importance of each factor. These are then analyzed in the GIS from which a map is build showing the potential suitable location for solar PV electricity plants. This process can be applied in other areas by using its own local data.

Table 8 Result of analysis of potential suitable location potential for decentralized solar PV electricity plants by district.

District	Suitable area (Rai*)				
	Highest	High	Moderate	Low	Unsuitable
Mueang Chiang Rai	2,374.19	11,813.21	30,246.78	35,718.77	40,373.00
Wiang Chai	270.07	6,561.24	13,518.25	8,297.30	132,413.55
Chiang Khong	0	0	0	4,372.70	265,736.81
Thoeng	0	3,102.00	3,854.93	5,587.76	299,543.83
Phan	766.60	14,173.45	29,794.50	15,982.30	244,868.05
Pa Daet	0	3.61	97.89	1,083.62	94,011.03
Mae Chan	359.63	2,180.61	5,347.00	11,722.08	230,923.62
Chiang Saen	0	0	0	4,674.38	203,825.15
Mae Sai	0	0	0	187,179.00	112,323.58
Mae Suai	0	0	0	16,584.65	363,116.57
Wiang Pa Pao	0	0	0	7,743.20	283,190.00
Phaya Mengrai	81.65	5,706.53	4,802.21	5,189.91	1,186,305.87
Wiang Kaen	0	0	0	2,399.07	152,842.21
Khun Tan	0	0	0	1,542.42	62,196.67
Mae Fa Luang	0	0	0	17,921.70	184,892.06
Mae Lao	188.03	2,515.31	2,202.00	4,386.84	70,059.55
Wiang Chiang Rung	0	0	0	2,827.17	121,279.45
Doi Luang	0	0	0	1,810.49	89,730.96
Total	4,040.17	46,055.96	89,863.56	335,023.36	4,137,631.96

*(1 Rai = 0.395 acre and 0.0016 square kilometers)

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