Selection of optimal places for constructions of renewable energy stations in Myanmar using analytic hierarchy process (AHP) method

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Abstract. The article discusses the formulation of the problem of choosing the optimal places for building renewable energy stations in Myanmar using the analytical hierarchical process (AHP) method. Today Myanmar is a developing country in Southeast Asia. Myanmar possesses a variety of energy resources, including renewable and non-renewable energy sources. Humans have especially used, and are now using, fossil fuels. After 2010, Myanmar began to focus heavily on renewable energy sources (RES). The Ministry of Electricity and Energy (MOEE) is the responsible ministry for the energy sector in Myanmar. MOEE is also responsible for the production, production and transportation of oil and gas. Myanmar has long been isolated from international markets, and funding sources have historically limited development and therefore pressure on its environment. Many of its resources remain relatively intact despite the lack of effective environmental regulations. However, as the country integrates into the world economy and its economic development are accelerating, resource degradation is growing rapidly. Deforestation of closed forests in recent years has been the fastest growing among large Southeast Asian countries, most of which are driven by plantation concessions and other large-scale projects. In order to reduce the use of fossil fuels and increase the use of renewable energy sources in Myanmar, it is necessary to investigate where and which RES are optimal depending on all situations.

1 Introduction

Myanmar is a state in the western part of the Indochina Peninsula of Asia. Until 1989, the country was officially called Burma. It is located between 9°32' and 28° 31' degrees north latitude and between 92°10' and 101° 11' east longitude. The area of the country is 678,500 km². In the west, Myanmar borders with Bangladesh and India, in the north and northeast with China, in the east with Laos, in the southeast with Thailand. The total length of the border is 5876 km, of which 2185 km are on the border with China, 1800 km - on the border with Thailand [1]. From the southwest, the country is washed by the waters of the Bay of Bengal, from the south - by the waters of the Andaman Sea. The length of the coastline is 2832 km. Myanmar includes the Mewi (Myei) archipelago, located in the

Andaman Sea. The length of the country from north to south is 2051 kilometers and 936 kilometers from west to east [2]. Two-thirds of Myanmar is located between the equator and the northern tropic; therefore, most of the country is dominated by a tropical and subtropical climate, formed under the influence of monsoons [3]. There are three seasons: rainy, lasting from late May to late October; cool - from late October to mid-February and hot - from mid-February to late May [4]. The average annual ambient temperature ranges from 22°C to 27°C, however, in 70% of the country's territory in March and April, the temperature exceeds 40°C during the day, however, in some northern regions located in high mountains, the temperature drops to 0°C in cool season [5]. 135 nationalities live in Myanmar. The country's population was over 60 million with an annual population growth of 0.8% in 2012. More than 70% of the country's population lives in rural areas in more than 60,000 villages. Myanmar had a total primary energy supply (TPES) of 16.57 Mtoe (Million tons of oil equivalent) in 2013. Electricity consumption was 8.71 TWh. 65% of the primary energy supply consists of biomass energy, which is used almost exclusively (97%) in the residential sector. Per capita energy consumption in Myanmar is one of the lowest in Southeast Asia due to low electrification and widespread poverty. An estimated 65% of the population is not connected to the national grid. However, energy consumption is growing rapidly, with a CAGR of 3.3% from 2000 to 2007. Most of Myanmar's electricity (74.7%) is generated by hydropower. The remainder is fossil fuels, of which gas is the main fuel (20.5%), followed by coal and oil. In 2017, Myanmar's installed electrical capacity was around 5 gigawatts (GW). The country plans to achieve 100% electrification by 2030. The country plans to produce 12% of all electricity from renewable sources by 2025. The total installed capacity of Myanmar as of May 2020 is 6,034 MW: 3,262 MW of hydropower (54%), 2,496 MW of natural gas (41%), 120 MW of coal (2%), 116 MW of diesel (2%), and 40 MW solar energy (1%). The cost of generating electricity was found to be 12 kkyat per kWh for public hydroelectric power plants, 72 kkyat per kWh for private hydropower plants, 150 to 190 kkyat per kWh for natural gas power plants, and 195 kkyat per kWh for solar power plants. Power plants. At the annual meeting of the Myanmar Oil and Gas Society on January 24, 2021, Minister mentioned that the country is moving to a new energy structure: hydropower - 40%, solar energy - 14%, domestic gas - 34% and LNG - 11%. This will bring the composition of renewable energy to 54% and the composition of clean fuel (natural gas) to 45% of the total installed capacity of 8,118 megawatts (MW). Myanmar's electrification rate is one of the lowest in Asia at 50% in December 2019. Electrification is especially low in rural areas, which are mostly not connected to the grid. In these areas, wood and biomass are used as the main sources of energy. Myanmar has abundant energy resources, especially hydropower and natural gas. In 2013, Myanmar exported 8,561 thousand toe of natural gas and 144 thousand toe of oil. The country is one of the top five energy exporters in the region and is the second largest natural gas exporter in the Asia-Pacific region after Indonesia. According to the World Energy Council, gas reserves are estimated at 244 Mtoe. Oil and coal play a lesser role, reserves are estimated at 7 and 1 Mtoe, respectively [6].

In fig. 1. map of Myanmar presented.

Fig. 1. Map of Myanmar.

1.1 State of the country

As of September 2014, out of 814 plants nationwide, the total generation capacity was 4,581 MW, of which 3,044 MW (66.46%) came from hydropower. The high dependence on hydropower causes unstable supply as the reservoirs behind the dams shrink during the

hot season. As of September 17, with 33% of the population having access to electricity, the peak load was 2,171 MW, the per capita consumption was 232 kilowatt-hours. Myanmar has presented a 15-year energy development plan to meet the growing demand for electricity, with plans to increase capacity from 4,581 MW to 29,000 MW by 2031. The Ministry of Electricity, expressed that the new plan involves the transition from hydropower to other sources of energy, including coal, natural gas, solar and wind energy. In 2031, Myanmar will have 41 power plants. [8] As of today, the Ministry of Electricity and Energy of Myanmar has expressed that a National Electricity Power Plan (NEPP) has already been established [9]. Buildings for electricity and the village that have already received electricity by November 2020.

Table 1. Buildings for electricity and villages that have already received electricity before November 2020.

No.	States and regions	Constructions for electricity	the villages that have already received electricity	
1	Kayar	4	4	
2	Kayin	67	55	
3	Chin	4	1	
4	Sagaing	944	939	63 villages with Pilot and Tr organizations
5	Bago(West)	652	532	
6	Bago(East)	564	521	
7	Magway	509	422	
8	Mon	68	53	
9	Rakhine	11	11	
10	Shan(South)	159	88	
11	Shan(North)	87	51	
12	Shan(East)	9	2	
13	Ayeyarwaddy	645	629	
14	Nay Pyi Taw	94	94	2 villages with the permission of the World Bank
	Sum of the Electricity supply company	3817	3402	
15	Yangon Electric Power Corporation	193	190	
16	Mandalay Power Supply Corporation	384	379	
	Sum	4394	3971

Fig. 2. According to the plan, the National Electricity Power Plan (NEPP), the Construction for electricity and the village that have already received electricity by November 2020.

Table 2. Future plan National Electricity Plan (NPFE), build for electricity for the remaining villages that do not yet receive electricity.

Future plan of the National Electric Power Plan (NEPP)	
the investment amount that will be use	The first step - After completing the construction for the village on the territory of 3.22 km, we build further with approximately \$117.95.
number of villages to build in	4700 village and 539674 families on the territory of 5 km from the Construction site
Current state for second step	The second step-has already invited a tender for the construction of electricity on the territory of 5 km
Approval of the Ministry of Electricity and Energy of Myanmar	After buying the necessary things to build for the villages, 59% have already come.
approximate time will end	November 2021

1.2 Renewable Energy in Myanmar

Renewable energy sources are sources based on constantly existing or periodically occurring energy flows in the environment. A typical example of such a source is solar radiation with a characteristic repetition period of 24 hours. Renewable energy is present in the environment in the form of energy that is not the result of purposeful human activity, and this is its distinctive feature.

Assessment of the requirements of agricultural electricity consumers, development of methods for assessing the categories of energy potential of RES resources in the context of socio-economic factors. Preliminary studies were conducted on rural consumption and the potential of Myanmar's renewable energy resources. By 2020, the prospective electricity consumption of rural and remote areas of Myanmar is projected to be 7,050 TW.h in the conditions of 2020.

According to the geographical location of the country, the main rural population lives in areas where it is quite possible to use renewable energy resources. In the central plains region of Myanmar, solar energy is available all year round. Wind power installations can be implemented on the west coast and in the central area. In these areas, the average annual speed at the height of the weather vane is over 5 m/s. These studies and figures have shown that the country has huge resources of RES.

2 Mathematical formulation

The objective of this paper is to present, discuss, and apply the principles and techniques of the analytic hierarchy process (AHP) in the prioritization and selection of projects in a portfolio. AHP is one of the main mathematical models currently available to support the decision theory.

3 Calculations to find the most optimal places for constructions of res in Myanmar

3.1 Myanmar solar energy resources

The solar energy potential in Myanmar is 51,973. 8 TW.h per year, with an average of more than 5 hours of sunshine per day. Despite the fact that most of Myanmar's electricity is generated by hydroelectric power, the country has a rich technical potential for solar energy, which is the highest in the Greater Mekong sub region; however, in terms of installed capacity, Myanmar lags far behind Thailand and Vietnam. The country aims to produce 8% of its electricity from renewable energy sources - wind and solar-by 2021 and 12% by 2025.

The calculations in this paper are based mainly on the data of "meteonorm" (2020).

Fig. 3. Cities that choose to optimize for constructions of Solar Energy Stations.

Table 3. Average monthly solar radiation in major cities in Myanmar (kWh / m² / month)

No	Location /Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Nay Pyi Taw	152	152	178	190	179	148	134	138	148	139	137	140
2.	Yangon	152	148	179	189	151	120	117	106	138	136	120	137
3.	Mandalay	140	145	165	180	180	145	122	138	142	128	130	133
4.	Myitkyina	121	120.5	150	158	158	110	105	128	112	110	125	126
5.	Lashio	141	142	169	179	180	140	130	141	140	130	135	132
6.	Taunggyi	160	162	182	195	180	155	138	140	150	140	139	145
7.	Kalay	145	140	165	185	190	150	138	145	140	139	142	140
8.	Pago	151	150	178	185	157	119	109	110	140	140	130	139
9.	Mawlamyine	150	145	173	185	150	119	115	95	144	140	128	137
10.	Dawei	145	140	179	188	139	112	125	101	145	140	130	145
11.	Myeik	145	144	178	185	150	115	125	97	135	150	133	139

Table 4. Average monthly solar radiation in cities at the middle part of Myanmar (kWh / m² / month).

No	Location /Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Yenangyaung	138	144	163	172	181	153	133	141	147	140	130	130
2.	Chauk	133	141	159	170	180	153	137	138	140	138	125	124
3.	Nyaung-U	132	140	158	167	180	150	140	136	136	135	123	122
4.	Myingyan	133	140	160	170	179	150	145	145	145	132	125	125
5.	Kyaukpadaung	137	143	163	170	182	155	143	143	145	139	129	127
6.	Natmauk	143	145	170	180	183	157	144	145	150	141	130	129
7.	Magway	143	150	170	180	180	150	130	140	150	142	130	133
8.	Pakokku	130	140	158	170	180	150	142	138	138	130	125	123

Table 5. Highest Temperatures in major cities in Myanmar (C).

No.	Location /Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Nay Pyi Taw	33.5	37	40	45	39	36	37	34.5	36	35.5	39	33.5
2.	Yangon	37	39	40	40	39	34	33	33	35	37	37.5	37.5
3.	Mandalay	34	38	42	42.5	42.5	38.5	39	37	37	37	36	34
4.	Myitkyina	25	28.5	31.5	34	35	34	32.5	32	33	32	29	26
5.	Lashio	25	29	33	34	34	33.5	33.5	34	34	32.5	29	27
6.	Taunggyi	25	28	30	32	33	30	30	28.5	28.5	28.5	27	24.5
7.	Kalay	29.5	35	39	38	37	35	35	34	35.5	37	34	32
8.	Pago	35.5	38	39	42	38	34.5	34.5	33.5	34	35.5	36	36.5
9.	Mawlamyine	35	37	39.5	41	38	35.5	35	33.5	34	34.5	37	34
10.	Dawei	35.5	38	39	40	37	35.5	37	33.5	34	34.5	35	35
11.	Myeik	35	36	36.5	37	36	34.5	33.5	33.5	33	34	35	35.5

Table 6. Highest Temperatures in cities at the middle part of Myanmar (C).

No.	Location /Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Yenangyaung	34.4	38	41	42.5	42	39.8	41	37.5	37.5	37	36.5	34.5
2.	Chauk	34.2	37	41.5	41.5	40	39	39.5	36.5	37	36	35.5	33
3.	Nyaung-U	34	37	42	42	41	38	38	37	36.5	37	35	34
4.	Myingyan	34	37	40.5	42	40.5	38	39	36.5	36.5	37	35.5	33
5.	Kyaukpadaung	32	36.5	39.5	41	39	37	38	35	36	35	35	31
6.	Natmauk	34	37	41	42	41	37	38	37	37	36.5	35	34
7.	Magway	33	37	41	42	41.5	37	38	36	37	36	35	33

8.	Pakokku	35	38	42	42	42.5	39	40	37	38	37	36.5	33
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3.1.1 Selection of the Site for the Construction of a RES Station by the “Analytical Hierarchy of Processes (AHP)” Method

In Myanmar, there are some places where there is no national network. The report selects places where there is no national network, for which the calculation using the Analytical Hierarchy of Processes method will show where it is better to build RES stations.

To build a hierarchy, the factors that are important for decision-making are selected, including:

- Resources - What energy is there in this place?
- Environment, Condition-Myanmar is still in a civil war in some regions. In general, there is no national network in such places. The government is trying to build hydroelectric power stations in places where there is no national grid. If these factors (war and energy potential) are not taken into account, people, investments, time, etc. will be lost.
- Transport-Especially in these regions, very dangerous transport. There are roads, but there is no safety. Sometimes there are bad roads.
- Potential - Weather, landslide, floods, etc.
- Cost-Prices often change for various reasons.
- Specialists-Engineers, experienced workers, assistants, etc.
- Security - Civil war on the border and in some other places. We need the help of the Army.
- Insurance-Insurance companies will provide a deposit for any event, but this applies to all situations?

Diagram 1. Selection of the most optimal Location for Solar Station using The “Analytical Hierarchy Process (AHP)” in Myanmar.

Diagram 2. Selection the most optimal Location for Solar Station using The “Analytical Hierarchy Process (AHP)” in the middle part of Myanmar.

Using pairwise comparisons, one can express the relative importance of one criterion over another. To do this, use the following procedure:

Let's set the values of the criteria in the form
1-equal, 2-moderate, 3-strong, 4-very strong, 5-extreme.

Using these criteria, we construct a matrix of paired comparisons.

	Resources	Environments	Transport	Potential	cost	Specialists	Security	Insurance
Resources	1/1	2/1	2/1	3/1	1/1	2/1	1/1	2/1
Environment	1/2	2/2	2/1	2/1	1/3	1/3	1/3	1/3
Transport	1/2	2/1	3/3	2/1	1/3	1/1	1/3	1/3
Potential	1/2	1/2	1/3	4/4	1/4	1/3	1/4	1/4
Cost	1/1	3/1	3/1	2/1	5/5	1/1	1/1	1/1
Specialists	1/2	2/1	2/1	2/1	1/1	6/6	1/1	1/1
Security	1/1	3/1	2/1	2/1	1/2	1/1	7/7	1/1
Insurance	1/2	2/1	1/1	2/1	1/1	1/1	1/1	8/8

Step 1. Squaring the matrix and converting fractions to decimals.

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

Step 2. Calculate the first eigenvector of the matrix (up to four decimal places).

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

“Multiply with the same matrix”

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

And then, get the show results as shown in table 7.

Table 7. Results by multiply with the same above matrix.

8.5	23.5	19.9999	26	8.5832	11.6665	9.0832	10.0832
3.9999	10.333	8.333	12.1664	3.16645	5.3331	3.3331	3.8331
4.33325	10.6664	10.6664	13.4998	3.83315	5.3331	3.9998	4.4998
2.2083	5.3332	4.8332	6.3332	1.98603889	2.91655	2.111039	2.611039
8	22	19.6666	25	6.9998	10.6665	7.4998	8.4998
6.5	18	15.6666	19.5	5.8332	8.3332	6.3332	6.8332
7	18.5	17.1666	22	6.1665	9.1665	6.6665	7.6665
6	16	14.6666	17.5	5.4999	7.3332	5.9999	6.4999

If add up all the columns from the table 7, will get a column matrix (Sum) as shown in Column 1.

Column 1. Results by adding all the columns from the table 7.

117.416
50.49805
56.8317
28.33257
108.3325
86.9994
94.3326
79.4995

If add all the numbers of this column, the sum is 622.2423.

If 622.2423 is multiply with the column column1, this result is as shown in column 2.

Column 2. Results get by multiply with the column1 and the sum of adding all number of column 1.

0.1887	Resources	1
0.0811	Environment	7
0.0913	Transport	6
0.0455	Potential	8
0.1741	Cost	2
0.1382	Specialists	4
0.1517	Security	3
0.128	Insurance	5

This is the result-an eigenvector.

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Nay Pyi Taw	.2	.1	.1	.03	.1	.2	.2	.2
Yangon	.08	.2	.2	.06	.2	.1	.1	.1
Mandalay	.09	.1	.1	.06	.1	.1	.1	.1
Myitkyina	.03	.03	.03	.1	.1	.03	.06	.06
Lashio	.06	.06	.06	.2	.03	.06	.03	.03
Taunggyi	.06	.06	.09	.08	.09	.09	.08	.1
Kalay	.08	.08	.06	.1	.06	.06	.06	.06
Pago	.1	.1	.1	.08	.1	.1	.09	.1
Mawlamyine	.1	.1	.1	.09	.08	.1	.08	.09
Dawei	.1	.09	.08	.1	.08	.08	.1	.08
Myeik	.1	.08	.08	.1	.06	.08	.1	.08

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Yenangyaung	.15	.15	.1	.15	.15	.1	.15	.1
Chauk	.1	.1	.1	.15	.1	.1	.1	.1
Nyaung – U	.1	.15	.15	.1	.17	.17	.15	.13
Myingyan	.1	.15	.1	.1	.1	.13	.15	.13
Kyaukpadaung	.1	.15	.15	.1	.13	.13	.1	.17
Natmauk	.15	.1	.1	.1	.1	.1	.1	.1
Magway	.15	.1	.15	.15	.15	.17	.15	.17
Pakokku	.15	.1	.15	.15	.1	.1	.1	.1

If multiply with the column 2 and the matrixes for the middle part of Myanmar and for the major cities of Myanmar, the results will show the most optimal locations.
The result for the major cities of Myanmar in table 8.

Table 8. Results that show what city is the most optimal for the major cities of Myanmar.

No.	Cities	Results	Rank
1	Nay Pyi Taw	0.03774	1
2	Yangon	0.006488	10
3	Mandalay	0.008217	9
4	Myitkyina	0.001365	11
5	Lashio	0.010446	7
6	Taunggyi	0.008292	8
7	Kalay	0.012136	6
8	Pago	0.0128	5
9	Mawlamyine	0.01354	4
10	Dawei	0.013775	2
11	Myeik	0.01401	3

The results for the middle part of Myanmar in table 9.

Table 9. Results that show what city is the most optimal for the middle part of Myanmar.

No.	Cities	Results	Rank
1	Yenangyaung	0.028	1
2	Chauk	0.008	7
3	Nyaung-U	0.009	6
4	Myingyan	0.004	8
5	Kyaukpadaung	0.017	5
6	Natmauk	0.02	3
7	Magway	0.022	2
8	Pakokku	0.019	4

The result shown is obtained.

Sum – 1. If the sum of places =1, the ranking is correct. Now a little more matrix algebra gives the solution to choose a place.

The result for the major cities of Myanmar is (0.03774) – the best place to build a solar station.

The result for the middle part of Myanmar is Yenangyaung (0.028) – the best place to build a solar station.

3.2 Myanmar wind energy resources

Myanmar's Department of Renewable Energy and Hydroelectric Power gives priority to the development of solar and wind energy. The Rakhine, Tanintharyi and Irrawaddy regions have been identified as areas with strong wind energy potential, but the potential for solar energy is higher than that of wind energy in Myanmar. Myanmar is building its first wind farm in Chaung Thar, Irrawaddy region, as part of a 30MW wind power project it is implementing jointly with China's Three Gorges Corporation.

The selection of a site for a large offshore wind farm operating in the unified energy system should be carried out in accordance with the following criteria: wind intensity; depth of the seabed; availability of transport infrastructure; possibility of technical connection of the projected wind farm to the power system; distance from the site to the substation ; absence of environmental and other restrictions (for example, economic, military or environmental activities should not be carried out on the proposed sites). The choice of the available area for the placement of offshore wind farms was made taking into account the absence of environmental and other restrictions. It was also revealed that almost the entire available area for offshore wind farms is promising in terms of wind intensity, since the average long-term wind speeds over the entire allocated territory at an altitude of 100 meters are higher than 6.7 m/s. Further selection of offshore wind farm sites on the previously selected available territory was made according to the criterion of the possibility of technical connection of the projected offshore wind farm to the power system.

An analysis of the location of existing 230 kW substations on the west coast of Myanmar allowed us to identify eight promising sites for offshore WES on the previously planned territory for offshore WES. Moreover, the sites were considered taking into account the depth of the sea up to 30 m, i.e. the possibility of placing wind power plants (wind turbines) of the proposed offshore WES on a fixed basis, and technical connection to the Program Complex 230 kW. The analysis of the possibility of technical connection of an offshore WES at the corresponding site to the nearest Program Complex allowed us to identify the power range of the projected offshore WES: from 30 MW (WES sites: 1, 3, 5, 6) to 80 MW (WES site 2). Information on Program Complex and offshore wind farm sites are presented in Table 10: the average distance from the WES to the shore r_1 ; the range of sea depth changes at the WES; the average distance from the WES to the nearest substations r_2 ; the power of transformers (PT) of substations in MVA; the PT load of substation's data in %; free capacity for the technical connection of offshore WES in MVA S_{free} ; approximate area available for the placement of WES $F_{available}$.

And Figure 4. Shows the location of substations and the selected sites located on the west coast of Myanmar and Data on electrical substations and offshore wind farm sites in table 10 [10].

Fig. 4. Locations of promising sites for offshore wind farms and substations of the Myanmar energy system.

Table 10. Data on electrical substations and offshore wind farm sites.

No	Locations/ substations	r_1 (From site of WES to shore, km)	Depth range, m	r_2 (from WES to substations, km)	Power of transformer (PT), MVA		loading power supply, %	Available power (MVA)	F_{WES} km ²
1	Pone Na Kyun	17,5	8- 17,1	49,32	1×100	100	70	30	17,5 6
2	Kyauk Phyu	12,82	25- 32	23,06	1×100+1×50	150	43	85	17,5 6

3	Taung Kote	32,8	20-30	77,8	1×100	100	64	36	17,5 6
4	A Toke	5,0-9,0	6-43,0	74	1×100	100	55	45	17,5 6
5	Pathein 1	11-16,0	17-36,0	116	2×50	100	65	35	17,5 6
6	Pathein 2	20,0 - 30	13-27,0 0	165	2×50	100	65	35	17,5 6
7	Mawlamyine 1	16-20,0	9-12,0	52	3×50	150	60	60	17,5 6
8	Mawlamyine 2	26-30	22	130	3×50	150	60	60	17,5 6

Diagram 3. Selection the most optimal Location for Wind Station using The “Analytical Hierarchy Process (AHP)” in offshore of Myanmar.

Using pairwise comparisons, one can express the relative importance of one criterion over another. To do this, use the following procedure:

Let's set the values of the criteria in the form

1-equal, 2-moderate, 3-strong, 4-very strong, 5-extreme.

Using these criteria, we construct a matrix of paired comparisons.

	Resources	Environments	Transport	Potential	cost	Specialists	Security	Insurance
Resources	1/1	2/1	2/1	3/1	1/1	2/1	1/1	2/1
Environment	1/2	2/2	2/1	2/1	1/3	1/3	1/3	1/3
Transport	1/2	2/1	3/3	2/1	1/3	1/1	1/3	1/3
Potential	1/2	1/2	1/3	4/4	1/4	1/3	1/4	1/4
Cost	1/1	3/1	3/1	2/1	5/5	1/1	1/1	1/1
Specialists	1/2	2/1	2/1	2/1	1/1	6/6	1/1	1/1
Security	1/1	3/1	2/1	2/1	1/2	1/1	7/7	1/1
Insurance	1/2	2/1	1/1	2/1	1/1	1/1	1/1	8/8

Step 1. Squaring the matrix and converting fractions to decimals.

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

Step 2. Calculate the first eigenvector of the matrix (up to four decimal places).

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

“Multiply with the same matrix”

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Resources	1	2	2	3	1	2	1	2
Environment	0.5	1	2	2	0.3333	0.3333	0.3333	0.3333
Transport	0.5	2	1	2	0.3333	1	0.3333	0.3333
Potential	0.5	0.5	0.3333	1	0.25	0.3333	0.25	0.25
Cost	1	3	3	2	1	1	1	1
Specialists	0.5	2	2	2	1	1	1	1
Security	1	3	2	2	0.5	1	1	1
Insurance	0.5	2	1	2	1	1	1	1

And then, get the show results as shown in table 11.

Table 11. Results by multiply with the same above matrix.

8.5	23.5	19.9999	26	8.5832	11.6665	9.0832	10.0832
3.9999	10.333	8.333	12.1664	3.16645	5.3331	3.3331	3.8331
4.33325	10.6664	10.6664	13.4998	3.83315	5.3331	3.9998	4.4998
2.2083	5.3332	4.8332	6.3332	1.98603889	2.91655	2.111039	2.611039
8	22	19.6666	25	6.9998	10.6665	7.4998	8.4998
6.5	18	15.6666	19.5	5.8332	8.3332	6.3332	6.8332
7	18.5	17.1666	22	6.1665	9.1665	6.6665	7.6665
6	16	14.6666	17.5	5.4999	7.3332	5.9999	6.4999

If add up all the columns from the table 11, will get a column matrix (Sum) as shown in Column 3.

Column 3. Results by adding all the columns from the table 11.

117.416
50.49805
56.8317
28.33257
108.3325
86.9994
94.3326
79.4995

If add all the numbers of this column, the sum is 622.2423.

If 622.2423 is multiply with the column column1, this result is as shown in column 4.

Column 4. Results get by multiply with the column 3 and the sum of adding all number of column 3.

0.1887	Resources	1
0.0811	Environment	7
0.0913	Transport	6
0.0455	Potential	8
0.1741	Cost	2
0.1382	Specialists	4
0.1517	Security	3
0.128	Insurance	5

This is the result-an eigenvector.

	Resources	Environment	Transport	Potential	Cost	Specialists	Security	Insurance
Pone Na Kyun	.1	.1	.1	.1	.1	.1	.05	.05
Kyauk Phu	.15	.1	.1	.1	.1	.1	.05	.05
Taung Kote	.1	.1	.1	.1	.1	.1	.05	.05
A Toke	.15	.1	.1	.1	.1	.1	.05	.05
Patheingyi 1	.1	.15	.15	.15	.15	.15	.2	.2
Patheingyi 2	.1	.15	.15	.15	.15	.15	.2	.2
Mawlamyine 1	.15	.15	.15	.15	.15	.15	.2	.2
Mawlamyine 2	.15	.15	.15	.15	.15	.15	.2	.2

If multiply with the column 4 and the matrixes for the offshore part of Myanmar, the results will show the most optimal locations.

The results for the offshore part of Myanmar in table 12.

Table 12. Results that show what city is the most optimal for the offshore part of Myanmar.

No.	Cities	Results	Rank
1	Pone Na Kyun	0.01887	3
2	Kyauk Phu	0.012165	6
3	Taung Kote	0.00913	7
4	A Toke	0.006825	8
5	Patheingyi 1	0.01741	4
6	Patheingyi 2	0.01382	5
7	Mawlamyine 1	0.022755	1
8	Mawlamyine 2	0.0192	2

The result shown is obtained.

Sum – 1. If the sum of places =1, the ranking is correct. Now a little more matrix algebra gives the solution to choose a place.

The result for the offshore part of Myanmar is Mawlamyine 1 (0.022755) – the best place to build a wind station.

4 Conclusions

In this paper, calculating parameters and optimizing the best place to construct Renewable Energy Stations. In Myanmar there are more seriously to build energy stations because of political reasons. There are many reasons to be considered in Myanmar. These reasons are changed as the criteria to build diagram to be optimized the most suitable place from many different places (anyway locations where can get renewable energy resources).

1. Information of the energy resources in Myanmar.

2. Solar and wind energy resources of Myanmar and selecting locations.
3. Building tree diagram to select the most optimal place from some places by using Analytic Hierarchy Process (AHP) method.
4. Calculations to find the most optimal places for constructions of RES in Myanmar.
5. Getting the most optimal places for constructions of RES in Myanmar.

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