

Research Article

Technical and Economic Study of Wind Power for an Educational Space in Hormozgan Provinc

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Abstract: In this research, power supply project of a school with 5 classrooms in Hormozgan Province in south of Iran through wind energy was studied. First, rate of the required energy of this school was estimated by reviewing electrical structures of the project. In the next phase, considering the required energy of this training place, the equipment required for the wind power including turbine, controller charge, inverter and battery bank has been calculated. Considering the cost price of this equipment, the primary investment costs of the power supply project of the school through wind energy have been calculated. The power supply charges of the project through the wide network which include power network costs, main cost and consumption costs have been calculated considering tariffs of the power company. At the end, economic analysis of the project was conducted by comparing these costs. Results obtained from this research indicate that considering different ways of power supply to the training places, it will be more cost effective to operate the wind power network than power network in case the distance between school and power network is about 2.85 km above and it is better to use the wind power network. In other cases, in case the wind power network is used, the primary investment will return after about 3 to 10 years and the wind power network will reach profitability whether the project needs to develop the power network or not and whether the consumed power rate is calculated with free or subsidized tariff.

Keywords: 5-Classroom school, economic analysis, power generation, wind energy

INTRODUCTION

In near future, renewable energies will play more effective role in supply of the energy in the world. Renewability, no contamination, expansion of these sources in the world and simple utilization made the renewable energy more attractive for the developing countries. For this reason, energy renewable sources have been regarded as important in the national and international plans and policies of the countries. Most regions of the country are regarded as arid and semiarid regions based on the climatic classifications. Considering increase of drought intensity in recent years, in case the energy obtained from hydraulic and thermal power plants is relied on, this country may face power shortage during drought years. Therefore, it is important to apply renewable energies in Iran. Wind energy is one of the best and the most economical methods of power generation among the renewable energies, which doesn't result in environmental pollution and is not exhaustible. The oldest method of using the wind energy dates back Ancient Iran. The Iranians successfully turned windlass for the first time using the wind power and brought water from their water wells to the farmlands. Today, use of this energy source is growing considerably. Origin of wind creation

is a simple issue. Since land is heated with sun unequally, therefore, there is lower thermal energy in Poles than in the tropical regions. Temperature changes more rapidly in the land and land is heated and cooled earlier than the seas. This global temperature change causes a global thermal exchange system and causes the still air to flow. Most of the energy which is available in wind movement can be found in high levels of atmosphere where continual speed of wind reaches more than 160 km/h. in low levels of wind; energy is lost due to friction with ground and atmosphere surface. Since most power is generated in high speed of wind, half of the energy is generated in 15% of function time of the turbine. As a result, wind power plants have no stable energy generation like the fuel power plants. The structures which use wind power should use the back-up generators when energy production rate is low in wind turbine.

Sadegh *et al.* (2010) said based on the statistics published by European Wind Energy Association, about 43% of the newly installed equipment which produces energy in Europe related to wind energy in 2008. Wind energy potential is about 15 times as much as the energy consumption in the world as one of the renewable sources of energy. The first discussion related to the related researches on use of wind energy

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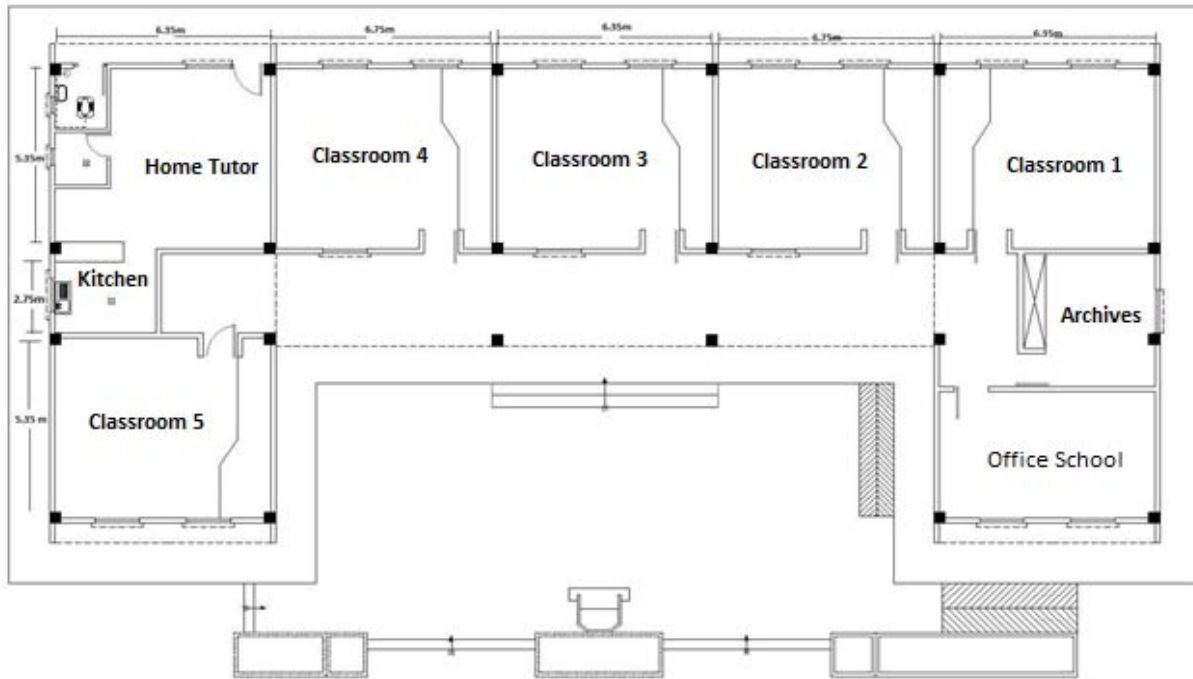


Fig. 1: Architectural plan of pilot school

is feasibility study and potential study of the discussed region in terms of wind intensity in different seasons of the year.

Mohammad Reza *et al.* (2010) determined potential of wind energy and selected the optimal point to construct wind power plant in Khorasan Province in northeast of Iran.

Adodka and Adewale (1992) and Ambrosini *et al.* (1992) conducted potential study of wind in some parts of the world based on the statistical methods. Our goal of this research includes feasibility study and design of power production system required for a training place in Hormozgan Province through the wind energy. Therefore, the financial estimate of project is prepared considering the current prices of equipment and structures. Economic analysis of the project will be conducted considering the results obtained from this research and comparison with the power supply and consumption costs through the power network.

In fact we want to study the final cost of wind power for an educational space in Hormozgan Province.

MATERIALS AND METHODS

Pilot school choice: After studying the technical parameters dependent on geographical place, site of the project and feasibility study of wind energy use for supply of electric energy, the consumable energy required for design of wind power production system was estimated in the next stage.

The related pilot project is a school with approximate area of 378 m² with 5 classrooms, restroom and hygienic service, office, pantry and filing

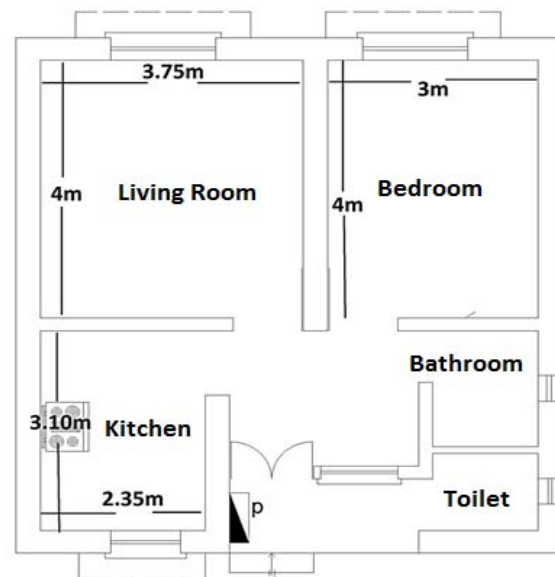


Fig. 2: Architectural plan of teacher's house

room as well as a teacher's house with approximate area of 62 m² with 2 bedrooms, hall, kitchen and hygienic service in order to supply electrical energy using the wind energy. Architectural plan and layout of the school and the teacher's house are shown in Fig. 1 and 2.

Geographical zone to be studied in this research is Hormozgan Province. Hormozgan Province is located in south of Iran between 25° and 24' and 28° and 57' of the latitude and between 53° and 41' and 59° and 15' of the latitude from Greenwich Meridian. This province

Table 1: Power required for pilot school

	Device name	Average power consumption of the device (W)	Number	Useful time of power consumption per day (h)	Daily power consumption (KWh)	Monthly power consumption (KWh)	Annual power consumption (KWh)
1	Air conditioner (18000 btu/h)	2000	2	4	16	480	5760
2	Air conditioner (24000 btu/h)	2500	6	4	60	1800	21600
3	LED Ceiling lights 2*20W	40	27	3	3.24	97.2	1166.4
4	LED Ceiling lights 10W	10	8	3	0.24	7.2	86.4
5	LED Wall lights 10W	10	12	8	0.96	28.8	345.6
6	Fans ventilators	50	3	4	0.6	18	216
7	Computer	200	7	4	5.6	168	2016
8	Television	100	2	10	2	60	720
9	Electric water heater	2000	1	0.5	1	30	360
10	Refrigerator	150	2	8	2.4	72	864
11	Electric kettle	2000	1	0.5	1	30	360
12	Buzzer	100	1	0.1	0.01	0.3	3.6
13	Copier device	700	1	1	0.7	21	252
14	Printer	500	1	1	0.5	15	180
15	Audio system	200	1	1	0.2	6	72
16	Washing machine	500	1	0.5	0.25	7.5	90
17	Ironing	2000	1	0.5	1	30	360
18	Ceiling fan	120	13	2	3.12	93.6	1123.2
19	Hair dryer	1500	1	0.2	0.3	9	108
Total power consumption required (KWh)					99.12	2973.6	35683.2

Table 2: Power required for teachers' home

	Device name	Average power consumption of the device (W)	Number	Useful time of power consumption per day (h)	Daily power consumption (KWh)	Monthly power consumption (KWh)	Annual power consumption (KWh)
1	Air conditioner (18000 btu/h)	2000	2	10	40	1200	14400
2	Air conditioner (24000 btu/h)	2500	0	0	0	0	0
3	LED Ceiling lights 2*20W	40	7	5	1.4	42	504
4	LED Ceiling lights 10W	10	3	4	0.12	3.6	43.2
5	LED Wall lights 10W	10	3	8	0.24	7.2	86.4
6	Fans ventilators	50	3	2	0.3	9	108
7	Computer	200	1	6	1.2	36	432
8	Television	100	1	10	1	30	360
9	Electric water heater	2000	1	0.5	1	30	360
10	Refrigerator	150	1	8	1.2	36	432
11	Electric kettle	2000	1	0.4	0.8	24	288
12	Buzzer	100	0	0	0	0	0
13	Copier device	700	0	0	0	0	0
14	Printer	500	0	0	0	0	0
15	Audio system	200	1	2	0.4	12	144
16	Washing machine	500	1	0.5	0.25	7.5	90
17	Ironing	2000	1	0.5	1	30	360
18	Ceiling fan	120	2	6	1.44	43.2	518.4
19	Hair dryer	1500	1	0.2	0.3	9	108
Total power consumption required (KWh)					50.65	1519.5	18234

has area of 68000 m². Study of the wind plans shows that wind has average speed of 5 to 6 m/s which is sufficient for production of wind power in most regions of this province except central part and its western shores. In limited part of the north of the province, the wind speed is averagely 7.5 m/s.

We conclude from the above facts that production potential of the wind power in Hormozgan Province is medium and it can be utilized. Eastern and northern regions of the province and southern islands have higher potential for production of wind power.

Estimation of required energy: After studying the technical parameters dependent on geographical place,

site of the project and feasibility study of wind energy use for supply of electric energy, the consumable energy required for design of wind power production system was estimated in the next stage. Consumption rate of the electrical energy for the school and teacher's house is given in Table 1 and 2 using plans of the electrical structures of this school based on consumption type, daily, monthly and annual times.

Considering results of Table 1 and 2, one can find that total power required for the entire project is 50.65+99.12 or proximately 150 kwh at night and day.

Required equipment: Wind power network is composed of 4 parts which include wind turbine,

Table 3: Power of wind turbine (25KW) of SabaNiroo company at different speeds

Row	Average wind speed (m/s)	Productivity in a day (kwh)
1	5	24 h×3500 W = 84 KWh
2	6	24 h×6000 W = 144 KWh
3	6.5	24 h×7000 W = 168 KWh
4	7	24 h×9500 W = 228 KWh

battery bank, controller charge and inverter which are calculated as follows considering the energy required for the school.

Wind turbine: The number of wind turbines and their nominal power are determined based on the required consumable power, average wind blow speed in the region and production rate of wind turbine in terms of average wind speed. Careful observation of the wind atlas map of Hormozgan Province shows that the maximum average speed of wind in some northern and eastern regions of the province is about 7 m/s. On the other hand, considering the results obtained from calculation of the consumable power, rate of the required electrical energy at each day and night is 150 kw/h. All plants manufacturing the wind turbines provide technical specifications catalogue with the product itself which includes a chart of turbine production rate in different speeds of wind.

Considering the presented catalogues, 25-kw turbine made by Saba Niroo Company, power production rate in different regions is obtained with average speed rate as shown in Table 3.

This turbine has three-phase output of 380 V and in case a unit of this turbine is installed in a region with average wind speed of 6 to 6.5 m/s, it can supply the power required for this project.

Battery bank: We calculate capacity of the battery bank so that the network can have storage capacity for supply of the consumable power. These consumed powers include:

- 2 kw for other consumptions of school office, rest room and teacher's house
- Consumable power for the gas coolers of 5 classrooms
- Consumable power for one gas cooler of school office
- Consumable power for one gas cooler of teacher's house
- Power required for saving in one day = [(5×2.5 KW)+(2×2 KW)+2 KW]×4 h = 74 KWh
- V_{OUT} = 220V
- Amount of consumption electrical current for 8 h = 74 KWh÷220 V ≈ 336.36 Ah

Voltage conversion ratio = 220 VAC÷48 VDC ≈ 4.58 ≈ 5

Current conversion ratio = 1÷Voltage conversion ratio ≈ 0.2

Amount of receive electrical current from the battery bank at night = 5×336.36 Ah ≈ 1681.82 Ah
Capacity of the battery bank required = 1681.82 Ah

When the power stored in batteries is used, in case we use total storage capacity, the batteries will be damaged and their life length will be shortened. Since the selected batteries in this network are of charge deep cycle type and are highly able to discharge them without any damage, we consider the maximum permissible discharge rate as 80% of total capacity of the battery bank, therefore, we have:

Capacity of the battery bank required with considering the maximum 80% discharge = 1681.82Ah÷%80≈2102.27 Ah.

Now if we select batteries with capacity of 200 amp-hours, the number of required batteries will be as follows:

Number of batteries (48V, 200Ah) = 2102.27Ah ÷ 200 Ah = 10.51 ≈ 10.

Considering that all batteries available in the market have 12-v terminal voltage and voltage of DC power network with voltage of 48v, one should make all four batteries of 12 v series and as a result, we need four times as many as the obtained batteries in the previous phase.

Number of batteries (12V, 200Ah) needed to form the battery bank = 4×10 = 40.

Controller charge: Battery bank formed in the previous part includes 10 rows of 200-amp-hour battery each with 4 batteries series with each other. Considering output of the turbine which is three-phase AC power for both rows of one three-phase charger of 60 Amp with output voltage of 48 V DC and there is need for 5 charge controllers.

Inverter: Suitable inverter to be used in this project is the one with input of 48 V DC and output of 220 V DC with perfect sine wave and frequency of 50 Hertz. Cheap invertors available in the market have high frequency harmonics in the output due to square or modified square output wave shape and these harmonics in high powers of 1 kw waste energy considerably and causes wear of these devices. Considering high power of some consumable tools such as gas cooler, it is necessary that an inverter with suitable power be considered separately for such charges. Table 4 shows the number and type of required

Table 4: Number and type of inverters for wind power system requirement

Consumer	Power consumption	Number	Type of inverter	Number
Air conditioner (18000 btu/h)	2 KW	4	2.5-3 KW	4
Air conditioner (24000 btu/h)	2.5 KW	6	2.5-3 KW	6
Electrical outlets of school and home tutor	3 KW (Asynchronous)	1	2.5-3 KW	1
Electrical outlets of home janitorial	3 KW (Asynchronous)	1	2.5-3 KW	1

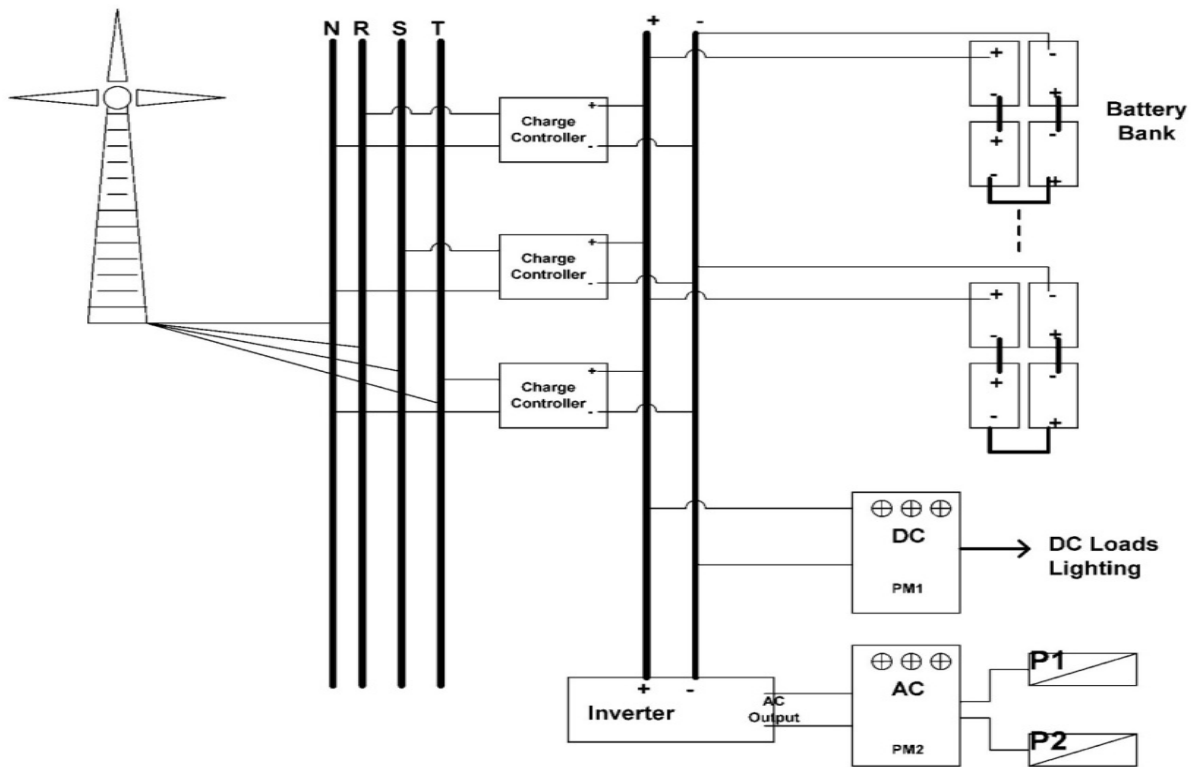


Fig. 3: Schematic of windpower

Table 5: Wind power system equipment list with costs

Equipment	Number	Unit	Unit price (\$)	Total cost (\$)	Useful lifetime	Manufacturer	Sales and service representative in Iran
1 Wind turbine(25KW) with equipment and installation	1	Device	40783	40783	25 years	Saba Niroom-Iran	Saba Niroom-Iran
2 Deep cycle battery (12V, 200Ah)	40	Piece	326.26	13050.4	10 years	Exide-England	Sufco Co.
3 Charge controller (60A- 3Phase)	5	Device	1486.19	7340.95	15 years	A.T.I.B-Italy	Sufco Co.
4 Sinus inverter 3KW	12	Device	1468.19	17834.28	15 years	HajirSanat-Iran	HajirSanat - Iran
Sum (\$)				79008.63			
1% of the total cost for miscellaneous equipment (\$)				790.09			
Total (\$)				79798.72			

inverters. Therefore, there is need for 12 inverters of 3 KW. It is necessary to note that light system is of LED lights type and is directly fed by the DC power of battery bank and doesn't need inverter.

Considering the cases mentioned in the previous section of Fig. 3 and Table 5, you can observe general scheme of the wind power network.

RESULTS AND DISCUSSION

Calculation of the primary investment cost for supply of power through the wind energy: After calculation and determination of type and number of wind power network with power supply capacity of 150 kw/h at night and day, the following table shows required equipment of this network.

The amount of the initial investment cost of wind power project is 79798.72\$.

Calculation of power supply and consumption expenses through the network: Power supply and consumption expenses through the network are classified into two major groups which include 1- power network and main development cost and 2- power consumption expense or the current expenses.

Power network and main development cost: Considering the distance between school and power network, one can consider different states for the network development expenses and we study 8 different states in this research:

- **First state:** Power supply without need for development of network and with subsidized power tariff
- **Second state:** Power supply without need for development of the network and with free power expense
- **Third state:** Need for development of medium pressure network with length of 500 m to supply power and with subsidized power tariff
- **Fourth state:** Need for development of medium pressure network with length of 500 m to supply power and with free power tariff
- **Fifth state:** Need for development of medium pressure network with length of 1km to supply power and with subsidized power tariff
- **Sixth state:** Need for development of medium pressure network with length of 1km to supply power and with free power tariff
- **Seventh state:** Need for development of medium pressure network with length of 2km to supply power and with subsidized power tariff
- **Eighth state:** Need for development of medium pressure network with length of 2 km to supply power and with free power tariff

In order to supply the consumable power, this project needs a 20 KVA power main which includes the following expenses:

- Expense of a 25 KVA transformator with installation cost, 7340.95 \$
- Subscription fee and it connection cost, 244.7\$

Development of the medium pressure power network for each meter costs averagely 24.47\$. Considering the information, primary cost of each of the above states is observed in Table 6.

The primary and current expenses of urban power use: You can find in Table 7 the Electricity tariffs with subsidy in 2012 in Hormozgan Province.

Considering the daily consumption rate of this project which has been estimated to be 40 kw/h at night and day, monthly consumption rate equals to 1200 kw/h of which subsidized power rate is 0.00897\$ for each kw. Free tariff of the consumable power in 2012 is 0.1101\$ for each kw/h of the consumable power. In calculation of the current expenses, 20% of the annual inflation rate will be added to the expenses. It is necessary to note that expenses of environmental pollution have not been considered to calculate the primary and current expenses of urban power use.

Economic analysis and return on investment: Considering comparison of the primary investment cost through wind energy with the power supply and consumption expenses through the power network, we conclude that:

Table 6: Electricity network development costs and subscription according to the 8 scenarios

Row	State	Initial costs (\$)
1	State 1	7, 585.65
2	State 2	7, 585.65
3	State 3	19, 820.55
4	State 4	19, 820.55
5	State 5	32, 055.46
6	State 6	32, 055.46
7	State 7	56, 525.29
8	State 8	56, 525.29

Table 7: Electricity tariffs with subsidy in 2012

Consumption 30 days per KWh	Cost per KWh (\$)
Less than 1000	0.0082
1001 to 2000	0.00897
2001 to 3000	0.0098
3001 to 3500	0.0408
3501 to 4500	0.0775
4501 to 6000	0.0938
More than 6000	0.11011

- If the distance between the project and power network is about 2.85 km above, it will be more cost effective to operate the wind power network independently of the network than the network development to the project site and it is better to use that.
- In case the monthly power consumption expense is paid through subsidized tariff and there is no need for development of the network in order to use the urban power and in case the wind power network is used, 76% of the primary investment will return after 10 years.
- In case the monthly power consumption expense is paid through free tariff and there is no need for development of the network in order to use the urban power and in case the wind power network is used, all of the primary investment will return after 10 years and if the wind power network is used after 10 years, the current expense will be compensated in the eleventh to fifteenth year.
- In case the monthly power consumption expense is paid through subsidized tariff and there is need for development of the network with length of 500 m in order to use the urban power and in case the wind power network is used, 91.4% of the primary investment will return after 10 years.
- In case the monthly power consumption expense is paid through free rate and there is need for development of the network with length of 500 m in order to use the urban power and in case the wind power network is used, all of the primary investment will return after 8 years and wind power network will be profitable afterward.
- In case the monthly power consumption expense is paid through subsidized tariff and there is need for development of the network with length of 1 km in order to use the urban power and in case the wind power network is used, all of the primary investment will return after 9 years and wind power network will be profitable afterward.

- In case the monthly power consumption expense is paid through free tariff and there is need for development of the network with length of 1 km in order to use the urban power and in case the wind power network is used, all of the primary investment will return after 6.5 years and wind power network will be profitable afterward.
- In case the monthly power consumption expense is paid through subsidized tariff and the project is distant from the power network by 2 km and in case the wind power network is used, all of the primary investment will return after 4 years and wind power network will be profitable afterward.
- In case the monthly power consumption expense is paid through free tariff and there is need for development of the network with length of 2 km in order to use the urban power and in case the wind power network is used, all of the primary investment will return after 3 years and wind power network will be profitable afterward.

CONCLUSION

After studying the technical parameters dependent on geographical place, site of the project and feasibility study of wind energy use for supply of electric energy, the consumable energy required for design of wind power production network was estimated in the next stage. Consumption rate of the electrical energy for training and door-keeping buildings was calculated with the required remarks using plans of the electrical and mechanical structures of a school with 5 classrooms based on consumption type, daily, monthly and annual times. Considering estimation of the required energy, the required structures for application of wind power have been calculated. These structures include the number of wind turbines and their nominal power, battery bank and other required equipment. Then the primary investment cost was estimated in USD based on the current price of the required equipments and total price of primary investment has been calculated to be 79580.75\$. In this study, costs of power supply for

this training place through the power network have been calculated based on costs of network development, subscription fee and consumable power costs in 8 states and considering distance between the school and power network as well as cost price of the consumable power. At the end, economic analysis of the project was conducted by comparing these costs. Results obtained from this research indicate that considering different states of power supply to the training place, it will be more cost effective to operate the wind power network than power network in case the distance between school and power network is about 2 km above and it is better to use the wind power network. In other cases, in case the wind power network is used, the primary investment will return after about 3 to 10 years and the wind power network will reach profitability and the wind system will reach economic profitability whether the project needs to develop the power network or not and whether the consumed power rate is calculated with free or subsidized tariff.

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