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# Evaluation of the Possibility of Instructing Power Plant in Esfahan Province Concerning Environmental, Social and Economic Criteria

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## Abstract

In order to study the construction of wind power plants in Esfahan province, the statistics of climatology, the wind speed in four areas of Brojen, Mourche Khart, Varzaneh, Moghar were obtained and then by using a 2.5 MB Tourbine with 928 AV, the potential of wind energy was measured according to environmental, social and economic criteria. The results showed that, the percentage of pollution diffusion in these power plants equals to 0.7 to 5 percent of fossil and gas fuel power plants so that investing on this type of energy can reduce the level of contaminants in the province up to 15 percent. On the other hand, replacing these power plants results in saving 7 million cubic meters water which is equivalent to 2 percent of water consumption. From the economic point of view, in addition to providing the cost of construction during two years, this can be a good potential to make money by reducing fuel consumption and the resulted sale.

**Keywords:** wind power plants, potential assessment, fossil fuel, environmental, social and economic

## Introduction

One of the problems of today's world is climate change which occurs because of humans' usual activity after industrial revolution to produce electricity. The best solution suggested to overcome the problemis to use reproducible resources compatible with environment, that wind energy is a sample of it. Wind energy like other resources of reproducible resources is geographically widespread and in the meanwhile is always available. This energy occurs as a result of natural factors like wind in cool and warm days of year and superficial factors such as human factors including machine movement (SANA, Third Report). Increasing use of fossil energy resources, reduction of available resources and increasing level of environmental pollution and greenhouse gases in parallel provide a suitable platform for using new energies. Now, Germany has the first place in reproducible energy, including wind energy which is used for producing electricity. Based on studies conducted by international association of wind energy, the global capacity of wind power plant from 2400 MB in 2001 reached to 158 MB in 2009. Based on evaluations made the same year in Europe and simultaneously in countries with more than 2 GB capacity, it was revealed that Germany with25.8 GW and Spain with 19.1 GW are in the first place and following them Italy, France, England, Portugal and Denmark possess a great part of wind energy market. According to chairman of the American wind energy association, the total wind energies installed in this country reach 48000 MW in 2015. The strategy of global association of wind energy is based on the desire to provide 10 percent of world required energy from the wind (SANA, Third Report; Gandom-kar,2010).

## Methods and Materials

In the present research, in order to construct wind power plants in Isfahan, first the records of wind rate in four areas including Brojen, Mourchekhort, Varzaneh and Mogharwereaccessed from the Renewable Energy Organization. According to standards of international meteorological organization standards, the vector parameter of wind is measured at aheight of 10 meters above ground in two synoptic meteorology and climatology stations of Meteorology Organization that in this study, the records of climatology station was taken into account. Then, since appropriate speed to use wind energy in producing windelectricity is about 4 meters per second the percentage of winds with higher than 4 meters per second was calculated. Afterwards, potential of this renewable energy was estimated. According to data provided by State Statistics agency and regional power organization of province, considering the environmental, social and economic criteria, the advantage of constructing wind power plants in province was studied.

**Area under study**

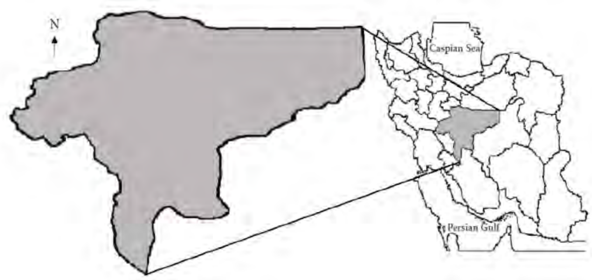



**Figure 1: Isfahan Province**

Population of Isfahan Province is approximately 4800000 people, 66 percent of them live in city and 34 percent reside in villages. Also, it is 107443 cubic meters wide which includes 6.6 percent of the country's area. This province is restricted to Markazi, Qom and Semnan province from north, to Fars and Kohkiloyeh and Boyer Ahmad from South and to Lorestan and ChaharMahalBakhtiari from east. The local power company of Isfahan has 212.288 electricity users among them 172611belonge to household sector. Also, the amount of distributed electricity in province equals to 1257296 MW per hour in 2012. In figure 2 the amount of electricity used with regard to consumption type in 2001 and 2006 to 2011 in Isfahan local electricity are shown (Ministry of the Interior, 2012):

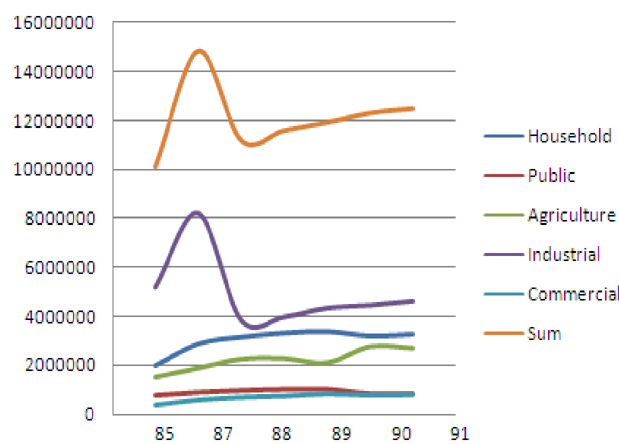



**Figure 2.The Amount of Electricity Consumed In Isfahan Province According To Consumption Type (MG per Hour) (Department of Statistics,2012)**

**Literature Review**

Using technology of wind energy dates back to thousands of years ago and use of vertical wind mill in Farsi borders and Aqanistanabout 200 BC and horizontal mills in Netherland and Mediterranean (Fleming &Probert,1984; Pasqualetii et al,2004; Musgrove, 2010). Historical records show that building wind millhas a long history in Iran, Iraq and Egypt and was used to crush grains and pump water. Dutch people also use these mills to dry flat areas, to press oil from grains and cut woods. History of using wind Turbine to produce electricity also dates back to early twentieth century. One of the important turning points in the history of wind energy is the presence of United States in wind power researches and developing it after oil crisis in 1973(De Carmoy,1978; Thomas & Robbins,1980; Gipe, 1991; Kaldellis & Zafirakis, 2011; Patel, 1999). Afterwards, between 1973 and 1986 the wing power market for household and agricultural use reached from 25 KW to 50-600 KW regarding wind fields(Ackermann & Söder, 2002). In 1980, the first wind electricity turbine connected to the global network. Following that,the first multi-Megawatt wind powerfarmcame into operation. Based on studies by global wind power, the capacity of wind power plants in 2010 reached 198 GW that China take the first place by satisfying 18.9 of his electricity needs by wind energy and US, India, Spain and Germany are in the second to fifth place. Now, Denmark with 21%, Portugal with 18%, Spain with 16% and Germany with 9% of wind power production of the total electricity have the first grade(SANA, Eight Report; World Wind Energy Association, 2011; Renewable Global Status Report,2011). The history of using wind power in Iran dates back to 900AD. At that time, Iranians of Sistan area used vertical wind mill for chores such as pulling water from wills and flouring wheat. A few centuries later Chinese used wind mill to pump water from wills and to grind rice. Four areas in Iran have the highest share in covering wind power in the country that Isfahan is one of these prone areas. Now, a large part of activities done in the country is planned to use large turbines (Ameri et al, 2006; Ameri & Lari,1997; Nowrouzi & Sadeghian, 2005).

**Application of Wind Turbines**

**A.** Non-power plant uses

**A. 1.** Water sucking wind pumps

Uses of water pumping technology in wind turbines include:

1. providing drinking water for animals in remote areas
2. watering in small scale
3. Water sucking from shallow areas to grow aquatic
4. providing drinking water

**A.2.** Application of small turbines to produce electricity

To provide the electricity for areas that providing their required electricity from global network is difficult and its fuel cost is economic.

**A. 3**. Battery charging

**B.** Power plant uses

Power plant uses of wind power turbines include applications attached to the electricity network. In order to provide household electric, business, industrial or commercial ions were used.

**Potential of Wind Energy**

The amount of electricity produced by a system of turning wind power depends on two factors of turbine characteristics and geographical condition of the area under study. The first factor includes turbine power, Router diagonal, and the low height of turbine and by geographical condition we mean the area climate, height from the sea level, the amount of area's up and downs and in general, all factors that influence the rate of area's wind (Bagiorgas et al,2007; Edem Agbeko, 2005). It should be noted that the second factor has more effective role in determining the level of electric energy because it determines the rate of wind(Lu & Yang, 2002). With regard to what mentioned in order to assess the potential of wind energy we need to estimate the turbine power, thus the following information was taken into account.

**Type of Turbine**

Type of turbine affects produced electricity. Also, the height of the tower and the diagonal of turbine's fliers influence the productive power of turbine. In addition, productive power, arrangement and space occupied by turbine significantly affect the number of turbines in the wind farm. In this study, the basis is to use turbines connected to the network. The average wind rate in the area under study should conform to the classification of wind turbinewhich complies with the international standard IEC61400-1. This standard is considered for wind turbines in different areas which conform to wind conditions of the area. Records of wind rate can be seen in the following table(Nourollahi,2011).

**Table 1: Classification of Wind Turbines (Nourollahi,2011)**

| IEC Wind Turbine Class | I | II | III | IV |
|---|---|---|---|---|
| Average wind speed at hub-height (m/s) | 10 | 8.5 | 7.5 | 6 |

In this study, the turbine AV 928- 2.5 MW connected to the network with class lla made in Germany was used with the following characteristics:

**Table 2: Characteristics of Turbine AV 928- 2.5 MW (Wind energy market)**

| | |
|---|---|
| Rotor diameter | 93.2 M |
| Swept area | 6882 M2 |
| Heightof tower | 80M, 90M |
| Nominal power | 2.5 MW |
| Output voltage | 690 V |
| Minimumwind speedto generate electricity | 3 m/s |
| Maximumwind speedto generate electricity | 25 m/s |

The power of wind turbine:

$$P = \frac{1}{2} C_p \rho A V^3 \quad (1)$$

is called the power coefficient which according to the definition is a percentage of wind power that turns into mechanical energy. According to Betz theory, in order to obtain the maximum energy possible, turbine should be located in such a way that the flow rate behind the router become 1.3 of flow rate before the router. In this case, the amount of power coefficient is assumed 0.593 which is lower in reality.

***-P Wind Power (Watt)***

-P is the specific weight of weather (density): wind density can be calculated by the following relationship represented by Oklahoma University of US.

$$\rho = 1.225 - (1.194 * 10^{-4} * z) \frac{kg}{m^3} \quad (2)$$

Since the height of Isfahan province from sea equals to 1570, wind density in this area equals to 1.037.

A - the circular area swept by router fliers (cubic meter)

V - relative wind rate

(SANA, Eight Report;Rahim-Zadeh et al,2009; Busby, 2002)Since turbine power evaluation needs wind rate, average rate of annual wind speed which is provided by renewable energy organization is shown in 10 meter height in the following table.

**Table 3: Speed and Rate of Wind(Office of Wind and Waves)**

| Target area | The mean wind speed at 10m height ($m/_s$) | The winds occurrence rate with speeds of more than 4 meters per second | Number of readings |
|---|---|---|---|
| Varzaneh | 3.27 | 33% | 1374 |
| Brojen | 2.83 | 27% | 783 |
| Moqar | 3.22 | 29% | 635 |
| Morche | 3.02 | 22% | 929 |

In order to choose areas with appropriate wind, we need to have information about the wind of area under study represented in table 3. Since the height of turbine's tower is 80 and 90 meters, in order to assess potential of wind in the area under study, the wind rate in the 80 and 90 meters height should be calculated that by using table 3 and help of equations of power rule, the changes of height is taken into account.

$$U_Z = U_{REF}(^Z/_{Z_{REF}})^{\alpha} \quad (3)$$

In this relationship$U_Z$ is the wind rate in the height of Z, $U_{REF}$is the wind rate in the basic height of $Z_{REF}$ (10 meters height) and $\alpha$coefficient is the change of wind direction whose method of calculation is calculated in form of a function of wind and height rate Hatami & Ganjavi, 2010; Nourollahi,2011).

$$\alpha = \frac{.37 - 0.088 \times \ln(U_Z)}{1 - 0.088 \times \ln(Z/10)} \quad (4)$$

By considering 3 and 4 equations,calculation of the areas under study will be as follows.

**Table 4: Wind Rate at the Height of Tower(Office of Wind and Waves; Nourollahi,2011)**

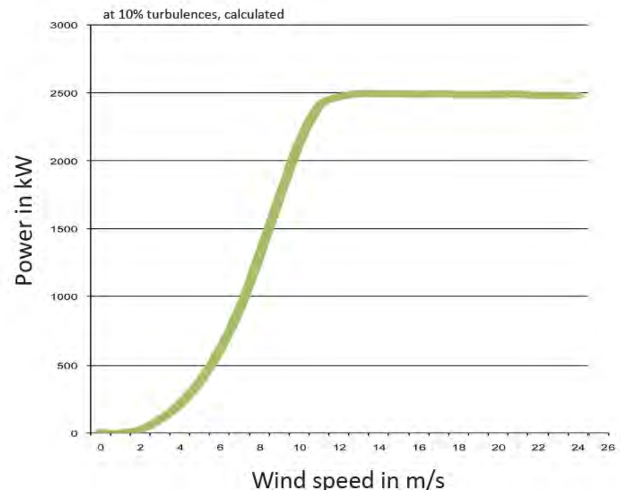
| Target area | The mean wind speed at 80m height ($m/_s$) | The mean wind speed at 90m height ($m/_s$) |
|---|---|---|
| Varzaneh | 5.68 | 5.86 |
| Brojen | 5.04 | 5.21 |
| Moqar | 5.61 | 5.79 |
| Morche | 5.32 | 5.5 |

Regarding the above table and formula 1, turbine tower can be calculatedaccording to the following table.

**Table 5:Assessment of Wind Potential Concerning Different Areas(Office of Wind and Waves; Wind energy market)**

| | | |
|---|---|---|
| Router diameter | 93.2 | |
| Swept area | 6882 | |
| Turbine power(KW) | | |
| Heightof tower | 80M | 90M |
| Varzaneh | 387.76 | 425.805 |
| Brojen | 270.900 | 299.248 |
| Moqar | 373.560 | 410.727 |
| Morche | 318.605 | 352.051 |

The above figures are also observable with regard to the table proposed by the manufacturer of turbine, German AVANTIS Company and taking into account the wind rate in figure 4.




(Wind energy market) According to the above figure and table 5 the nominalpower of electricity production is estimated between 300 to 500 KW. Accordingly, if we want to replace a 200 MW wind power plant with afossil fuel power plant or gas turbine of the province, we need a 400-667 turbines.

**Environmental Effect of Wind Power Development**

Among renewable energies, wind is one of the most economical methods to produce electricity whichdoes not result in environmental pollution. Increasing environmental pollution derived from burning fossil fuel cause global warming, creation of greenhouse phenomenon and acidic raining, also necessity of CO gas release duplicates the need to save fossil fuels and double attention to using this huge resource of energy. In fact, wind power does not cause environmental effects of contaminants such as $SO_X$ ، $NO_X$ ، $CO_X$ ،hydrocarbons and other greenhouse and poisonous gases, dirt and water pollution whose compensation costs are not taken into account in building fossil power plants.

**The Figure Represented By the Manufacturer of Turbine**

**Table 6: The Environmental Impacts of Wing Power Plants and Comparison with Heat Power Plants(SANA, Eight Report; Presidency and Strategic Planning Offices,2012; Kargari &Mastouri,2010; Nazari et al,2009)**

| Type of power plant | Fossil fuel power plant | | | Gas turbine power plant | | | Wind power plant |
|---|---|---|---|---|---|---|---|
| The level of greenhouse gas distribution | .59 | | | $1.13\frac{kg}{kwh}$ | | | 8-30 $\frac{gr}{kwh}CO_{eq2}$ |
| | $CO_2$ | $NO_x$ | $**\ SO_2$ | $CO_2$ | $NO_x$ | $SO_2$ | |
| | $450\frac{gr}{kwh}$ | $2.295\frac{gr}{kwh}$ | $4.33\frac{gr}{mws}$ | $640\frac{gr}{kwh}$ | $2.4\frac{gr}{kwh}$ | $2.75\frac{gr}{kwh}$ | |
| The amount of reducing environmental contaminants by wind power plant | $CO_2$ | CO *** | | $SO_2$ | $NO_X$ | | Particulars |
| | 850 | 1 | | 2.4 – $2.9\frac{gr}{kwh}$ | 2.6 $\frac{gr}{kwh}$ | | 55 $\frac{gr}{kwh}$ |
| Percentage of greenhouse gas diffusion in wind power plant | Compared to the fossil power plant | | | | Compared to the gas turbine power plant | | |
| | 1.3 - 5 % | | | | .7 – 2.6 % | | |
| The consumption level of thermal power plant in the province | Gasoline | | Mazut | | | | Gas |
| | 120.9 $\frac{m^3}{mwh}$ | | 155.9 $\frac{lit}{mwh}$ | | | | 13.7 $\frac{lit}{mwh}$ |

*Distribution of greenhouse gases equivalent to carbon dioxide
**ConcerningShahidRajaee power plant of Qazvin
***Compared to the fossil fuel power plant

With regard to table 6, the impact of replacing a 200 MW wind power plant with fossil powerplants and gas turbines of Isfahan province can be observed in the following table.

**** Figures mentioned are related the minimum level of consumption.

On the other hand, there are social costs in all usual options of fossil fuel, and World Wind Energy Association (WWEA), assimilated these costs to Ice Mountain whose huge costs are not considered in economic analysis. Empowering social structures because of wind energy nature which usually pays attention to the remote areas and new employment opportunities which is one of its instances will result in much advancement in rural areas. These environmental and social costs can be seen in the following table.

**Table 7: Analysis of Replacing 200MW Wind Power Plant with Fossil or Gas Fuel Power Plants (Presidency and Strategic Planning Offices,2012; Kargari &Mastouri,2010; Nazari et al,2009; Saidi,2007)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Reduction of greenhouse gases by removing one of units of ShahidMontazeripower plants, Isfahan, southern Isfahan, FooladMobarakeh or Iron fusion of Isfahan* | | | | | | |
| | $CO_2$ | $NO_x$ | $SO_2$ | $CO_2$ | $NO_x$ | $SO_2$ |
| | 1529496 $(\frac{Ton}{Year})$ | 7800 $(\frac{Ton}{Year})$ | 52981 $(\frac{Ton}{Year})$ | 2250882 $(\frac{Ton}{Year})$ | 11479 $(\frac{Ton}{Year})$ | 77970 $(\frac{Ton}{Year})$ |
| Reduction of greenhouse gases by removing one of Hasa, Kashan gas power plants | Hasa | | | Kashan | | |
| | 672768 $(\frac{Ton}{Year})$ | 25229 $\frac{Ton}{Year}$ | 28908 $\frac{Ton}{Year}$ | 3201254 $\frac{Ton}{Year}$ | 120047 $\frac{Ton}{Year}$ | 137554 $\frac{Ton}{Year}$ |
| Reduction of environmental contaminants by wind power plant | $CO_2(\frac{Ton}{Year})$ | $SO_2\ (\frac{Ton}{Year})$ | CO | $NO_X(\frac{Ton}{Year})$ | $(\frac{Ton}{Year})$Particulars | |
| | 1489200 | -5080842048 | 1752000 | 4555 | 96360 | |
| Reduction of fuel consumption in case of replacing it with esteem power plants | Isfahan iron fusion | | ShahidMohammad Montazeri | | Other power plants | |
| | Gas$(\frac{m^3}{year})$ | Gasolin$(\frac{m^3}{year})$ | Gas$(\frac{m^3}{year})$ | Mazut$(\frac{m^3}{year})$ | Gas$(\frac{m^3}{year})$ | Gasoline $(\frac{m^3}{year})$ |
| reduction of fuel consumption in case of replacing it with gas | 410924592 | 46564.6 | 1209473928 | 6238444 | 604736964 | 685268 |
| | Hassa | | | Kashan | | |
| | Gas$(\frac{m^3}{year})$ | Gasoline $(\frac{m^3}{year})$ | | Gas$(\frac{m^3}{year})$ | Gasoline $(\frac{m^3}{year})$ | |
| | 127090080 | 144014 | | 423633600 | 480048 | |
| Saving water in fossil fuel power plants | Iron fusion $(\frac{Ton}{Year})$ | | | Other power plants $(\frac{Ton}{Year})$ | | |
| | 7502940 | | | 5098320 | | |

*Esteem power plants with 35% efficiency –136 MW iron fusionand the remaining more than 200 MW

**Gas power plants with 35% efficiency – Hassa with 42 MW and Kashan with more than 200 MW of a combined cycle with 50% efficiency

***20% of fuel of ShahidMontazeri power plant and 80% Mazut

According to table 7, extracting Isfahan iron fusion power plant of the production circuit will be able to reduce 159277 tones dopant per year and this figure will reach 2340331 tones per yearfor other esteem power plants of the province by removing one of 200 MW units. Also, this level of reduction for Hassa gas power plants and Kashan combined cycle will be equal to 6781817 and 32270141 tones per year. Moreover theestablishment of one 200 MW wind power plant will reduce more than 15% of the environmental contaminants of the province.

**Economy of Wind Power Plant**

For the technological improvement, wind electricity has got a competitive power with usual fossil fuel resources. If,in addition to the costs of providing establishment costs, the environmental and social costs are considered in calculations, wind electricity can be supplied cheaper than other technologies of producing electricity. According to latest information received from Iran statistics organization and areal electricity of Isfahan province in 2012, the amount of electricity distributed is equal to 1257296 MW per hour that construction of a 200 MW wind power plant will satisfy 15 percent of electrical needs of the province. The investment costs for each Kilo Watt per hour for production of this power plant is estimated 5 cents, also costs of investment to establish a wind power plant is estimated 100 dollars per kilo watt that about 750 dollars ofit is the costs of equipment and preparation of the site and installation and establishment. Costs of repair and maintenance of wind turbines according to studies is estimated as 491 dollars per kilo watt for the first 2 years , 6.2 dollars per kilo watt for years three to ten and 6.9 dollars per kilo watt till the twentieth year of use is estimated. Accordingly, costs of construction and establishment is estimated 200 million dollar, electricity production costs 87 dollars per year and repairing and maintenance for the life time of wind power plant according to the formula proposed by power ministry in 2013 which is determined 4442 rials per each kilo watt per hour of the produced electricity, the income of selling electricity for such a power plant will be about 311 million dollars per year. For a more detailed analysis of being economic and non-economicof wind power plants, similar costs of a fossil fuel power plant and a gas power plant will be analyzed.

With regard to costs of reducing carbon dioxide according to studies conducted in the joint plan of environment group of power ministry and Jaikacompany during 1995 and 1999,6 dollars will be paid per each tone reduction in carbon dioxide. Accordingly, in order to reduce contaminants of a 200 MW fossil fuel power plant in the province, we should pay 152 million dollar per year that this figure for gas power plant with similar capacity will reach 3.2 million dollar per year. This cost about a 200 MW power plant is about 3 million dollar per year which is equal to 1.5 percent of environmental costs of gas and esteem power plants. Social costs of esteem and gas power plants also by considering the fuel price of FBO Persian Golf l of foreign and expenses and contaminant gases and greenhouse gases based on EPA coefficients of US is estimated 0.023 dollars per KW/h and 0.026 dollars per KW/h that each year will put a cost of 40 to 45 million dollar for the province and consequently the country. Fixed costs for repair and maintenance of a 200 MW gas power plant is estimated 72000 dollars per year and for fossil fuel power plants is estimated 99200 dollars per year and the non-fixed costs will be estimated 2277600 dollars and 700800 dollars per year respectively. Also, the fuel of fossil and gas power plants by paying subside also according to analysis made were estimated 45017640, 53520972 dollars per year( Peyman-Pak &Akbari, 2010; Rahimi et al,2009; Ikrami &Sadeghi,2009; Ministry of Energy, 2012; KhiljiAsadi, &Safaei,2003).

Despite the costs of construction, utilization, production maintenance and repair as well as social costs and air pollution are considered for the three power plants, the government will pay 290 million dollarsfor the gas power plantsin the first year and 4 million dollars per year after construction.

**Conclusion**

Increasing population growth along with urban and economic developments intensifies the need for more electricity production in the country. At the present time, about 98 percent of required electricity power for the country comes from fossil fuel power plants. However, due to the limited resources of fossil fuels, achieving environmental criteria for sustainable use of renewable energy is necessary and inevitable. One of those kinds is the wind energy that can be utilized as a primary resource to provide electricity needed for a province. According to extensive researches in recent years by the Renewable Energy Organization of Iran, researches indicate that Isfahan Province is highly predisposed to take advantage of wind energy. This study showed regions like Varzaneh, Maghar, Broujen, and MourcheKhortthat almost cover four geographical zones of the province (South, North, West and Central), meet the minimum wind speed necessary to invest in such a place in order to profit from the wind energy. Research revealed that investment so as to build a 200-megawatt wind power plant will be capable to comply with 14 percent of the province's electricity whole requirement and around 50 percent of household electricity consumption. Such a wind power plant, if replacing a gas power plant, could annually prevent about 2 million tons of greenhouse gas emissions. This amount for fossil fuel power plants rests one million tons per year. Investing on this renewable energy can reduce the level of contaminants in the province up to 15 percent. According to recent studies, the level of emissions at wind power plants is estimated 0.7 to 5 percent of the gas and fossil fuels. Although the plant's construction and electricity production costs are estimated to have a total of $ 287 million, the proceeds from the sale will be capable to compensate the primary high costs. Also, if the annual fuel cost savings in power plants, plus the social and air pollution costs were considered, investment for such kind of energy will be economical. Furthermore, the annual saving fuel power plant based on international trade, is estimated at least 3,558 barrels of oil - equivalent to $ 380,628 - per year. Looking at the statistics released by the Directorate of Isfahan Environmental Protection, it can be found that the air quality situation in the province in air pollution measurement stations has been declared unsafe at least twice in recent months. However, the wind power plants will contribute greatly to the improvement of air quality. Other advantages of those power plants that can be referred here are being active ceaselessly, developing deprived areas culturally and economically, as well as leading to the reduction of water consumption in the province. According to the present study, such power plants can reduce water consumption about 7 million cubic meters per year, which is about 2 percent of water used in the province annually. Due to the high costs of wind power planets construction and commissioning, one of the best strategies that may help the province to set policies to benefit the wind power can be of advantage of construction, leases, and transfer contracts. In these types of contracts, private investors take the responsibility to build the construction project and the Government repays the costs of private sector from renting the project and in this way, the ownership of the project returned to the State. Despite the appropriate potentials for wind energy applications, owing to the absence of substantial investments in renewable energy applications, the lack of appropriate technologies for utilization of this energy source and finally, the existence of the fierce rival cheap source of fossil fuels, the utilization of existing potential in this area is confronted a sever difficulty.

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