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ORIGINAL ARTICLE

Simulation and Economic Optimization of Wind Turbines and Photovoltaic hybrid System with Storage Battery and Hydrogen Tank (case study the city of Yazd)

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ABSTRACT : The aim of this study is to simulate wind and solar hybrid system to meet the load needed for a residential unit in the city of Yazd. The hybrid system consists of photovoltaic cell and wind turbines that the storages battery and hydrogen tank will be used in two ways for storing electric power surplus electric power and hydrogen. In this regard, first, the intensities of solar radiation and wind were taken from the National Weather Service for the years 2013-2014 then were considered in the Homer software as input. In order to that the storing electric energy has a high safety and variety, two storages were used. Wind reduces the 98% percent of the price of electricity is produced. As well as an increase of almost 0.5 kWh / m2 / day . Intensity of solar radiation to reduce the price of 0.38

Keywords: optimization, photovoltaic cell, wind turbine, simulation ,hydrogen production.

Introduction

In recent years, a growing trend in energy consumption in the world, especially in the power sector has been established that due to the sensitivities of the world in protecting the environment and reducing greenhouse-gas emissions, has caused to use of other sources of non-fossil sources generating electricity such as renewable energies(wind & solar). Now, the use of these energy sources to replace fossil energy with respect to environmental and economic Features is the main concern of energy policymakers including the withdrawal of this type of energy. The renewable energy such as wind generators (WG) and photovoltaic (PV) which has made significant progress can be named. However, each of the above technologies has a number of disadvantages, for example, wind and solar have a high dependency on ambient conditions, but with the combination of technologies, a hybrid system suitable for production the power can be reached. The groups of power production systems fed energy sources and work combined and supplements together are known as hybrid systems.[14-15-16-17] Since these systems are fed from two or more sources of energy have a higher reliability in compared with systems that have a source for generating electricity. Solar and wind are among the most common of energy resources. Hybrid photovoltaic systems and wind turbines can be widely and suitably supply the needs of the network. In some hybrid systems to resolve the daily fluctuations, the home battery cell is used. [10-12-16]

Desired site [Yazd]

Yazd is the first adobe city and the second largest ancient city in the world. The city of Yazd is situated in the valley of dry and vast between the mountains Shirkooh & kharanaq, with longitude of 54 minutes and 24 ° East and latitude 31 degrees 25 minutes North is a city of the north of the Maybod city and is limited from the east to the city of Bahabad and valleys of the western province of Isfahan, south of the city of Taft, Abarkuh and Mehriz. Locate on in the central part of the plateau covers most unfavorable natural factors prevail on the central plateau of Iran as well. Low rainfall and high evaporation, away from the sea, near the desert and vast salt, low relative humidity combined with the heat too, are factors , which are one of the most arid regions in Yazd, has made it as a most dry in Iran. A side from that, in this area there are temperature fluctuations. Its average height above the sea level is 1,200 meters and the humidity is 7% too.[2]

Wind data

In this study, we've collected data for the years 2014-2013 from the meteorological wind Yazd province, and then this data, has been considered as input the Homer software that accordingly, the annual mean wind value by the software is obtained 2.49 m/s. The blowing diagram for study region can be seen in Figure 1.[3]

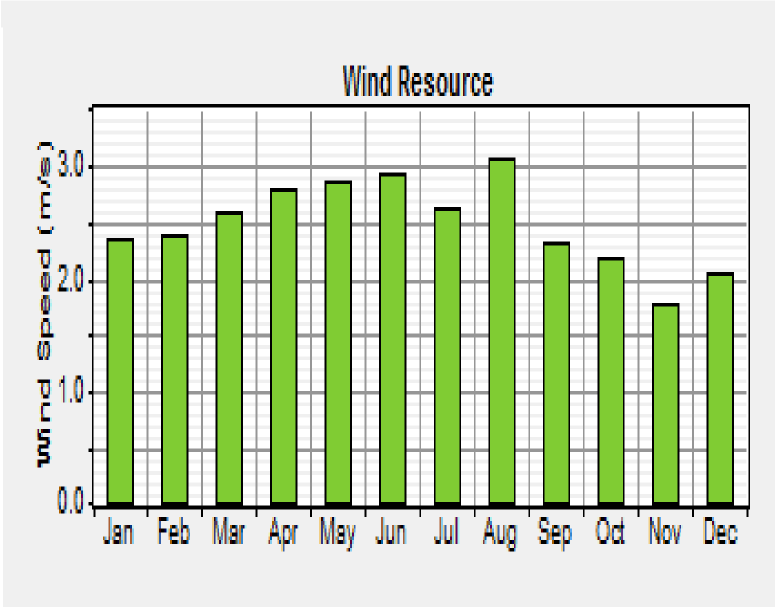

Figure 1 graphs the wind speed in the study area for the years (2014-2013)

According to the above graph it can be concluded that the highest speed of 3.06 meters per second, is for August and the lowest rate with an average speed of 1.76 meters per second is for November.

Solar radiation

In this study, data on sun severely for years 2014-2013 were collected from the National Weather Service in Yazd province, and then this data was intended as input software. Accordingly, the average annual solar radiation by the application was obtained 5.41 kWh / m2 / d 5.41 which its diagram is visible in Figure 2. [2

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.610	3.470
February	0.655	4.550
March	0.600	5.170
April	0.588	5.970
May	0.618	6.870
June	0.634	7.260
July	0.624	7.020
August	0.642	6.720
September	0.653	5.950
October	0.655	4.860
November	0.635	3.780
December	0.607	3.210

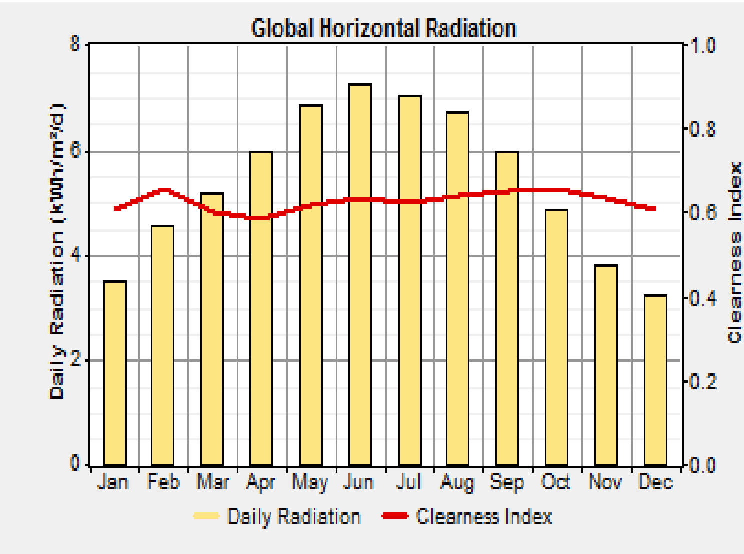

Figure . 2 the annual radiation-year (2014-2013)

According to the chart above, the maximum intensity is on June with an average of 7.26 kWh / m2 / d and the lowest intensity of solar radiation is on December with an average of 3.21 kWh / m2 / d.

Electrical load

The electrical load demand for residential units in the city of Yazd is considered which the total entire power in a day is 22 kwh /d and the load peak value is 2.15 kw , that this amount can be seen in detailed in Table 1 and Figure 3.[1]

Table 1. Table Estimated daily intake once a residential unit

Equipment	Rate of consumption(kw)	Time
Cooler	12Kw	1-4 10-16 17-18 19-20 21-22
Television	2kw	7-9 19-1
light bulb into house	.51kw	24-1 19-24
light bulb into Enclosure	1.05kw	1-4
washing machine	1kw	9-10
Steam Iron	1kw	11-12
Computer	.1kw	10-11
Juicers	.2kw	21-22
Refrigerator	3.6kw	Total nights
vacuum cleaner	1kw	8-9

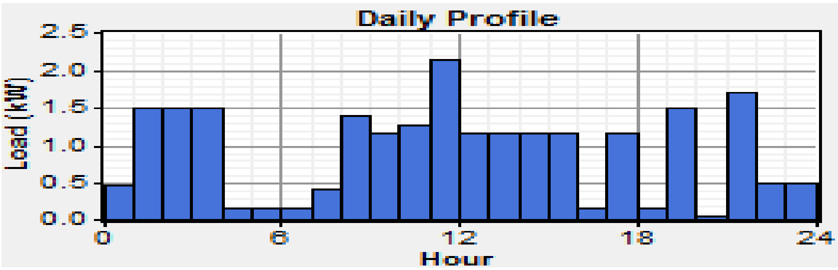

Figure.3 the load electrical for a target residential unit

Hybrid system equipment

Target hybrid system consists of devices such as wind turbines, photovoltaic cells, converters DC / AC, water electrolysis device, hydrogen tank and fuel cell systems, which all explanations and details of the hybrid system is described below:

Wind turbine

Wind energy can be passed through the blades and vanes then transfers torque energy to a generator motor extracted, the amount of power obtained from a wind turbine can be obtained by Equation 1: [4-5-6]

$$P = \frac{1}{2}\alpha\rho\pi r^2 v^3 \quad 1)$$

when the P is the converted power in watts, α is the coefficient of efficiency (which is related to turbine design), ρ is wind density in kilograms per cubic meter (kg/m3), r is the turbine torque radius in meters and v is wind velocity in m/s.

So that it can meet the requirements of the times. According to the mentioned materials the wind turbine Fuhrlander 30 KwAc was used in the study which the specifications of the turbine can be seen in Table 2 and power graphs can be seen in terms of wind speed in Figure 4.

Table 2 wind turbine characteristics Fuhrlander 30 KwAc [10]

Manufacturer Country	Rotor diameter	Tower	Rated power
Germany	13m	30m	30kw

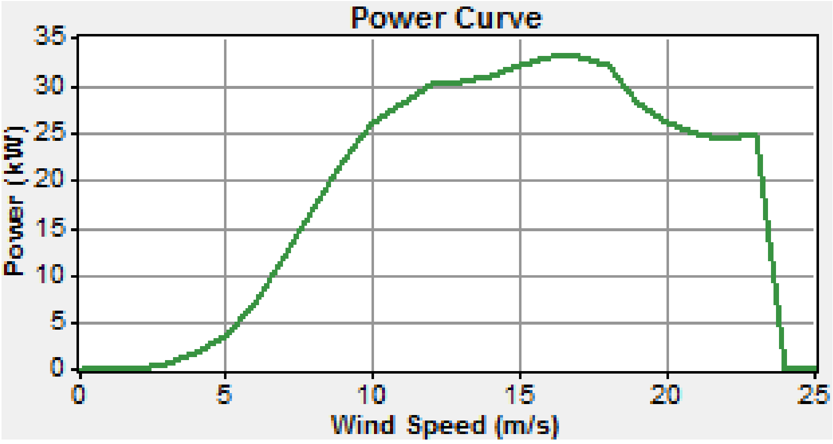

Figure . 4 Turbine power generation character

According to the diagram, the maximum power generation in wind turbine character which is 33 kW is for wind speed with 16 meters per second and minimizes speed for the power generation is 2.4 meters per second , and maximum wind speed to brake wind turbines torque is 24 meters per second.

Solar cell

The solar cell is a device that converts the sunlight energy to energy directly. The power output of solar cells is dependent to solar radiation intensity which the amount of power obtained from solar radiation can be achieved by relationship 2:[11-12-13]

PPV = YPVfpv [GT / GT STC] [1 + αP (TC-TC STC)] (2)

Table . 3 crystal silicon solar cell characteristics

Percent of losses against of rise Temperature	Temperature	output	Cost of maintenance **($)**	Cost of Replacement **($)**	Initial capital **($)**	tracking	Type of cell
-5	47	13	10	2500	3000	No tracking	Crystal silicon

Converter
Converter is indeed converting the power from DC to AC, or vice versa. The converter can be used to convert direct current to alternating current. Inverter, converts the DC voltage from solar modules into AC voltage to power for consumer makers. In that type of current production systems which the demand is different from power electronic, converters can be used to establish production and demand.

Table .4 Converter Profiles [11]

Cost of maintenance**($)**	Cost of Replacement **($)**	Initial capital **($)**	Longevity	Output
10	750	800	15 year	90./.

Electrolyzer
Water electrolysis is a method of hydrogen production, and if the required electricity to split water supplies from renewable energy sources, it is considered as a clean fuel. Water electrolysis devices compatible with a variety of renewable energy well and allow to distributed generation of hydrogen systems to manage their consumption at peak hours, and provide somewhat the shortage of power in the grid network by use the stored hydrogen and its use in fuel cells. In water electrolysis method, by passing direct current electricity from the water, it will be decomposes into its components gases H2 and O2. In this analysis the alkaline electrolyzer is used.[12]

Table .5 details of technical the electrolyzer

Cost of maintenance($)	Cost of Replacement ($)	Initial capital ($)	Longevity	Output
20	1500	2000	15 year	85./.

Hydrogen tank

Hydrogen storage has economic advantages in compared to electrochemical batteries to storage in long time. The density of hydrogen per unit mass is too higher but due to low gas density, its energy density per value is too low. In order to obtain the maximum energy value, it is requires the huge amount of energy is storaged. Hydrogen storages in the cases of solid, liquid and gass and storaging the gass hydrogen is one of the most simple, common and economic methods of storage hydrogen. [13]

Table .6 Hydrogen tank profiles

Cost of maintenance($)	Cost of Replacement ($)	Initial capital ($)	Longevity
15	1200	1300	25year

Fuel cell

Hydrogen can be used in different features but the most important characteristics of hydrogen is its use ability in fuel cells to produce electrical energy without causing environmental pollution and high efficiency. Fuel cells, is a electrochemical system which convert the chemical energy of fuel directly the electrical energy, and in it, the fuel is continuously injected to the anode electrode and oxygen to the cathode electrode and electrochemical reactions at the electrodes done and electric current is established by generate electric potential. In this design a polymer electrolyte membrane fuel cell system has been used. [12]

Table .7 cost of FC

Cost of maintenance ($)	Cost of Replacement ($)	Initial capital ($)	Longevity
20	1500	2000	15000h

Battery

Battery is used for storing excess energy. In the design a lithium-ion battery is used which its full profile and details can be seen in the figure below.

Table .8 Technical specifications in lithium battery

Nominal capacity	360Ah
Nominal voltage	6v
Round trip efficiency	85%
Min.stste of charge	30%
Float life	10yrs
Max.charge rate	1A/Ah
Max.charge current	10A
Lifetime throughput	KWH 1.075
Suggested value	1.167KWH
Max.Capacity	391Ah
Capacity ratio	.241
Rate constant	1.85 1/hr
Initial capital ($)	270
Cost of Replacement ($)	150
Cost of maintenance ($)	.2

Simulation

In this technology, the electricity required for water electrolysis plant to split water into its constituent elements of hydrogen and oxygen gases is provided from photovoltaic cells and wind turbines. Hydrogen produced from water electrolysis device is compressed by passing hydrogen compressor plant, and stored in a tank until a certain pressure to use in the fuel cell at different times and by a process of electrochemical reaction, hydrogen and oxygen react together and produce electricity. During the project term, water electrolysis system, storage tank hydrogen, wind turbine and transformers will be used until the end of the project and do not need to replace. In some cases, installation costs of solar modules, wiring, DC, the cost of modules installed Overall the system is overlooked and ignored:

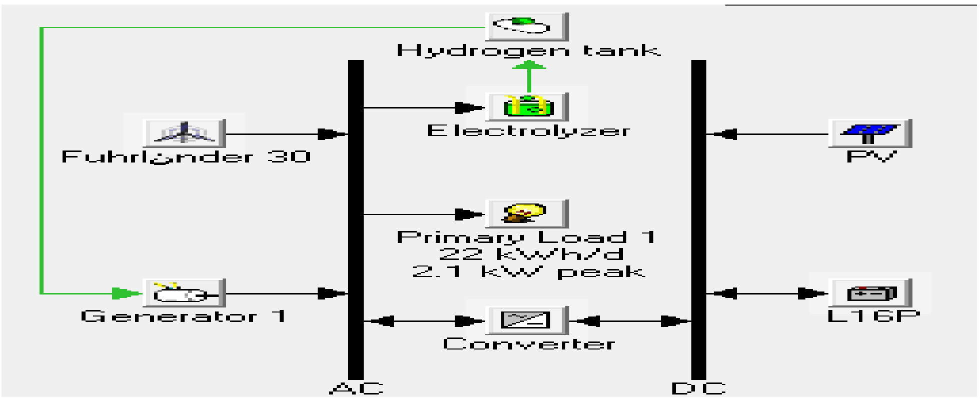

Figure .5 wind and solar hybrid system design with Homer software

Simulation analysis of solar and wind hybrid system in tables and figures presented below in which the costs related to energy systems with life 15-20 year average is calculated.

Table .9 analysis results of simulated solar and wind hybrid system

Equipment	Quantity
Solar of cell	9
Wind Turbine	1
Generator	1.9
Battery	15
Invertor	15
Electrolyzer	1.5
Hydrogen tank	3.7
Initial capital (**$**)	55.780
Operating cost(**$** /y)	3.614
Total NPC(**$**)	101.9
COE(**$**/ KWH)	./999

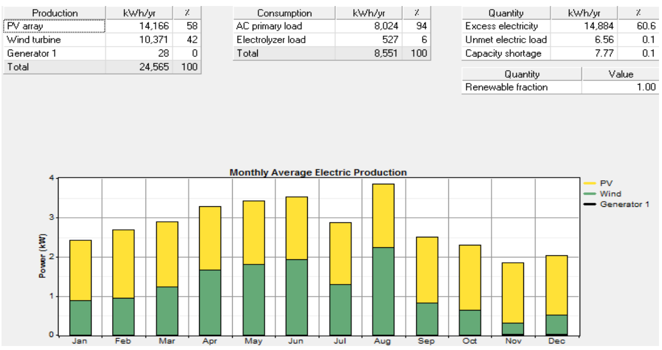

Figure .6 electricity productions during the year

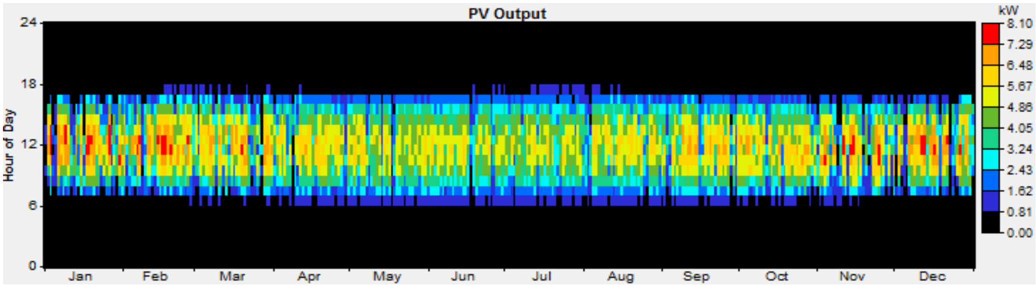

Figure .7 the amount of energy produced from photovoltaic cells over a year

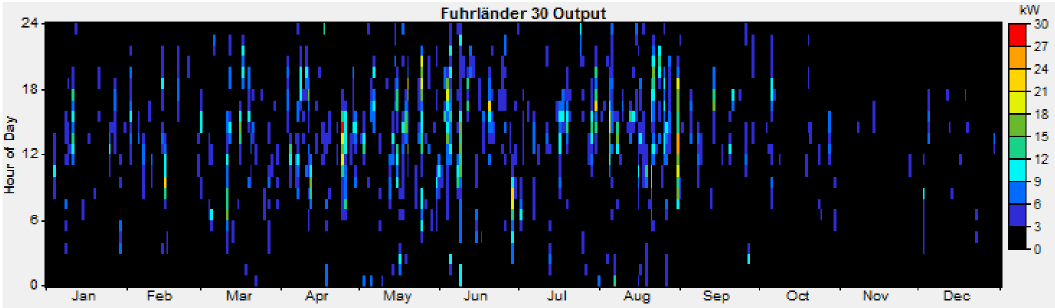

Figure .8 the amount of energy produced from wind turbines

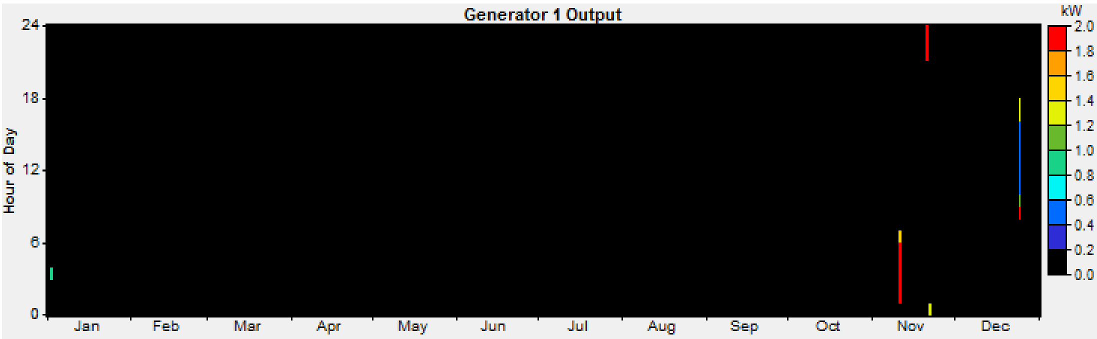

Figure .9 the amount of energy produced by the fuel cell during a year

Sensitivity analysis

Wind

Because wind speed may vary in subsequent years and the mean value changes, so we apply the sensitivity analysis on wind speed which the average wind speed in the area sizes (3.4) considered and ran the program again. Following results were obtained:

Table .10set of system solutions regard to sensitivity analysis on wind

Equipment	wind 4m/s	wind 3m/s	wind 2.5m/s
Solar of cell	6	9	9
Wind Turbine	1	1	1
Generator	1	1	1.9
Battery	15	15	15
Invertor	15	15	15
Electrolyzer	1	1	1.5
Hydrogen tank	2	2	3.7
Initial capital **($)**	48.325	52.825	55.780
Operating cost($ /y)	3.416	3.541	3.614
Total NPC**($)**	91.99	98.9	101.9
COE($/ KWH)	./896	./956	./994

That the above system, the electric power production for speeds average(2.49-3-4) meters per second to separate energy generators is as follows:

Table .11 the electric power production to 2.49 m/s average annual wind speed to separate generator

Production	Kwh/yr	Percent
Pv array	14.166	58
Wind turbin	10.371	42
Genrator	28	0
Total	24.565	100

Table .12 electric power production amount for average annual wind speed of 3 m/s to separate generators:

Production	Kwh/yr	Percent
Pv array	14.166	42
Wind turbin	19.491	58
Genrator	6	0
Total	33.664	100

Table .13 electric power production amount for average annual wind speed of 4 m/s separate generator.

Production	Kwh/yr	Percent
Pv array	9.444	17
Wind turbin	44.947	83
Genrator	0	0
Total	54.391	100

Sun

Since radiation intensity may vary in subsequent years and the mean value changes, so we apply the sensitivity analysis on radiation intensity which consider the radiation intensity average in sizes (5,41,6) and ran the program again. The results was achieved as following:

Table .14system solutions set in view of the sensitivity analysis on the intensity of solar radiation

Equipment	Sensivity of Intensity solar radiation 5.41 kWh/m²/d	Sensivity of Intensity solar radiation 6 kWh/m²/d
Solar of cell	9	9
Wind Turbine	1	1
Generator	1.9	1
Battery	15	15
Invertor	15	15
Electrolyzer	1.5	1
Hydrogen tank	3.7	2
Initial capital **($)**	55.780	52.82
Operating cost($ /y)	3.614	3.58
Total NPC**($)**	101.9	98.63
COE($/ KWH)	./999	./961

For above system power amount of electric for the intensity of solar radiation to separate electrical energy generator is as follows:

Table .15 electric power production amount for the average annual solar radiation intensity 5.41 kWh / m2 / d to separate generators

Production	Kwh/yr	Percent
Pv array	14.166	58
Wind turbin	10.371	42
Genrator	28	0
Total	24.565	100

Table .16 electric power production amount for the average annual solar radiation intensity 6 kWh / m2 / d separate generators

Production	Kwh/yr	Percent
Pv array	15.623	60
Wind turbin	10.371	40
Genrator	11	0
Total	26.005	100

Conclusion

According to our simulations and sensitivity analysis conducted on wind speed and intensity of the solar radiation, it is observed that wind speed and intensity of solar radiation is more in the study area the mentioned system will be economic and with increase to a one meter per second wind and a temperature in solar radiation intensity, almost a considerable amount of the total investment cost is reduced and the cost of electricity generated by this system is reduced too but it is not competitive with fossil systems still but taking into account the development of renewable energy technologies and environmental pollution, nd reduce the fossils fuels it can be a good choice.

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