Energy Farm Design, Case Study: Dezfoul in Khouzestan Province

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Abstract:
Today, energy plays a particular role in world's economy and politics. As fossil fuels caused major industrial developments in the twentieth century, energy will be the key element of development in future centuries. It is clear that all countries in the world can no longer be relied on traditional and limited energy sources for sustainable development. So, applying renewable energies as a clean energy seems necessary. The aim of this study is to introduce some of the renewable energy sources' application in a collection called Energy Farm. A farm in Dezfoul in Khuzestan province, located in the southwest of Iran, was selected as the case study and the use of solar, wind, biogas and fuel cells energies was evaluated and the energy balance analysis was conducted in there. According to calculations in designed energy farm, 12260 liters of ethanol will be produced in the biogas system in every cultivating season. Wind turbine produces about 13.6 kW power which is used in the electrolysis process. Moreover, the fuel cell system produces 5425 and 102 kWh from biological and electrical hydrogen sources, respectively. The energy which is produced from the biological hydrogen source of the fuel cell system is produced by all clover symbiotic microorganisms.

Keywords: Solar Energy, Bioethanol, Fuel Cell, Wind Turbine, Energy Farm

1. Introduction

In the third millennium world faces dominant changes in every aspect which necessitate changing in the way of living. Lack of consideration and application of modern techniques in the Global Village will result in retardation, frustration and inefficient movement in each country. Increasing demand for energy on the one hand and decreasing fossil fuel resources on the other hand, have influenced on energy supply all over the world and have made Energy the most important issues of the globe.

The first renewable energy is solar energy which thesedays, in most developing countries, has been used in much consumption such as rural electricity supply, expansion of communication services, water pumping, cathodic protection, street lighting and etc.

Almost all forms of energy originate from the Sun. In most areas of the Earth, the average of receivable solar energy is two kilowatts per square meters. The exact amount of receivable radiation differs spatially and temporally in terms of geographical zone, topography, cloud cover or sunny hours per day and the other factors. Iran is located in the southern half of the northern temperate zone between the orbits of 25° 30´ to 39° 47´ north and 45° 5´ to 63° 18´ East (in relation to Greenwich Meridian).

Much of the central deserts of Iran receiving 4.5 to 5.2 kWh/m^2 solar energy on average on a horizontal surface of the sun. Among the numerous applications of solar energy, photovoltaic pumping systems have been widely welcomed in the past two decades. According to reports of the World Bank, ten thousand photovoltaic pumps was installed and put into operation up to1993, and this number was reached to sixty thousand up to 1998 (Odeh et al, 2005). Since the maximum water demand during the growing season coincides with the peak solar radiation, water requirements of the plant can be provided by free energy of the Sun. Especially in the southern regions of Iran which, the receivable solar energy reach to 5.75 kWh per square meters, with the application of pressurized irrigation systems and photovoltaic pumps, energy and water use efficiency can be maximized.

Another source of renewable energies is biogas. Today, the problem such as environmental pollution of fossil fuels, which has influence on the ecological conditions of ecosystems, has been led to use of biofuels through many countries. Technical knowledge of bioethanol production is only restricted to USA, Sweden and Brazil. The World total production of bioethanol and biodiesel was 33 billion liters in 2004 (Majer et al, 2008). While in 2005, about 15 billion liters of bioethanol was only produced in Brazil (RNCOS Industry research solutions, 2006). In 2008, only in USA and Brazil more than 40 billion liters of bioethanol (approximately 50 billion liters) (RNCOS Industry research solutions, 2010) and about 3 billion liters of biodiesel were produced (Teramoy, 2008). It is anticipated that the global production of bioethanol and biodiesel will reach to more than 95 and 15 billion liters respectively by the end of 2014 (Kumar, 2009). Since the plan of replacing 10 percent of transportation fuels with biofuels by 2020, ethanol production has significantly increased in recent years (Shavandi, 2014). Currently, 83 percent of biofuels which is consumed in the world is bioethanol and the remaining is biodiesel with a small insignificant percentage of bioboutanol and biocrouzin. The aim of this survey is producing bioethanol from sugar cane fermentation. In the following more description about the design of the biogas system is explained.

Wind energy is one of the main types of renewable energies. And humankind has been thought about using wind energy for supplying industrial demand. About 2.5 percent of the solar energy that reaches the earth is converted into wind and about 35 percent of wind energy is in 1 km of earth's surface (Majer et al, 2008). Human has used wind energy for powering boats and sailing ships and windmills in the past. Currently, by regarding to the items listed above and economic efficiency, considering wind energy as a source of renewable and clean energy for sustainable development is necessary. In Iran, there are much potential for installation and operation of wind power turbines. And according to its economic plausibility, studies and investment in this type of renewable energy, development and application of Wind Energy is promising in this country.

Hydrogen is generally produced with three methods that include the use of fossil fuels, the direct use of water and biological methods. Using Hydrogen in Fuel cells can produce high efficient energy without environmental pollution, which is the most important feature of Hydrogen. The fuel cell is an electrochemical system that converts the chemical energy of fuel directly into electrical energy using water electrolysis. Water electrolysis is one of the most common methods for hydrogen production (Shiroodi et al, 2009). Hydrogen production is possible by using fossil fuels or electrochemical methods, but these methods depend on fossil resources directly or indirectly, which are not sustainable. Biological production of hydrogen by microorganisms is a new horizon for development which produces hydrogen from renewable sources. Biological production of hydrogen is normally done everywhere under anaerobic conditions. A wide range of bacteria in swamps, sewers and hot springs can produce hydrogen, carbon dioxide, alcohol and the other metabolites from organic materials (Naeempour et al, 2009).

2. Farm Schematic

Considering that the solar radiation and wind speed in the southern parts of Iran is suitable for energy production and on the other hand these areas have a good climate for growing sugar cane, Dezfoul agricultural lands were selected for case study as the region was agricultural land Dezfoul. Dezfoul in Khuzestan province in the northern latitudes 4/32, 38/48 ° East longitude and altitude of 143 meters above sea level. At least 5 hours of sunshine in the city and up to 10 hours
Dezfoul City in Khuzestan Province is located in the latitude of 32.4 N degrees and Longitude of 48.38 E and the altitude of 143 meters above sea level. The maximum and minimum sunshine hours in the city are 10 and 5 hrs respectively. The climate of the region is suitable for simultaneous planting of sugarcane and clover. The area of the Energy Farm was considered 2 hectares. Sugarcane and clover are planted on ridges and inside rivers respectively. The width of the ridges is 1.13 meter and the width of rivers is 0.7 meter. The farm schematic and general layout of generators are shown in Figure 1. Manifolds (the second order supplying pipes) are shown with M in the figure.

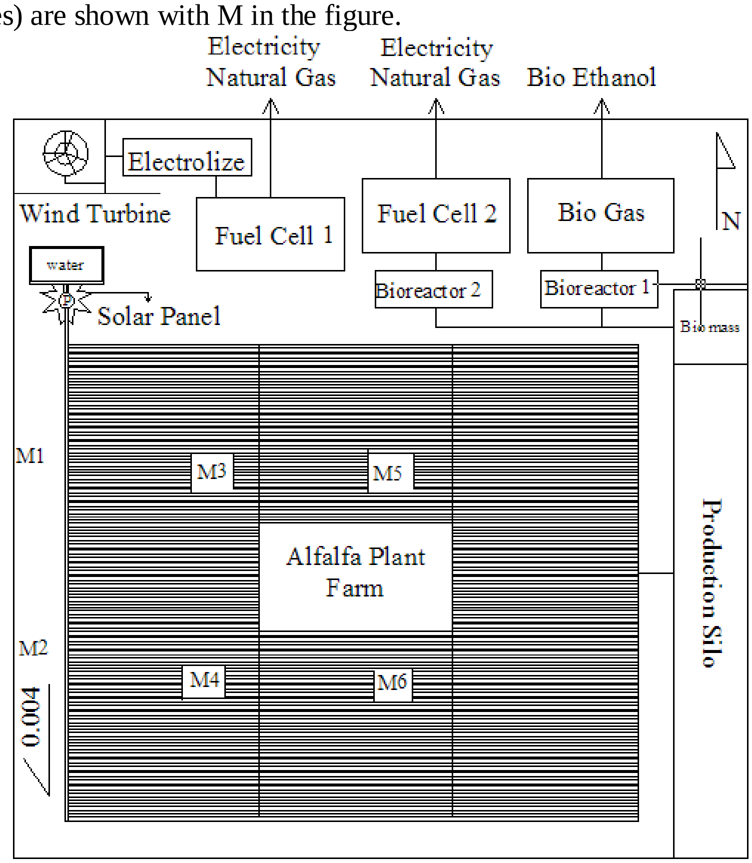

Figure 1. The Energy Farm schematic

3. Energy System Design

3.1. Solar Irrigation System

Much of the electricity which is consumed in agriculture is used for pumping water from wells. Moreover the pumps operate with very low efficiency such about 28 percent. On the other hand, the cost of consuming energy during the life of the pump is 10 to 20 times the cost of pump installation which is the initial investment (www.majlis.ir). In Iran from 1997 to 2005, the total energy consumption in agriculture sector was increased with a slope of 1.3 percent per year from 33.1 to 36.8 million oil barrel. Whereas by applying the solar pumps in addition to using the sun's free energy, maintenance costs of the system and environmental problems will decrease.

Solar pumping system consisting of five main parts: Electrical solar panels, pump controller, pump, water storage and battery. The power for pump operation is produced by the array of solar panels. The electricity which is produced by photovoltaic panels is Direct Current (DC). The supply of electric power from solar panels to pumps is managed by a controller which protects the pumps against electrical fluctuations and provides a constant flow. The size of solar pumps is determined based on the required pressure head and flow rate. The storing mechanism in solar pumps can be either water storage or battery. Storing water is the cheapest and the most reliable. But, battery can save power to be used at night or in cloudy days. Using battery increases the maintenance cost compare to water tank. Drip irrigation system has the highest efficiency between other irrigation systems. Therefore, in order to using water and energy (by reducing the photovoltaic panel area and pump power requirement) efficiently, drip irrigation is preferred to sprinkler irrigation and hydroflumes.

In general, irrigation systems are designed for times of peak crop water needs. The monthly net crop water requirements are determined based on a set of climatic parameters. Measuring the actual evapotranspiration (ET) which is the soil evaporation and crop transpiration in natural conditions, is very difficult and practically impossible. Therefore some indirect methods like empirical equations have been developed. Penman equation is a common method for potential ET estimation. CROPWAT model which has developed by FAO, is used to calculate the crop water requirement based on Penman-Monthis Method in dry and wet climate conditions. The model can be used for:

1- Development of irrigation tables considering the field practical conditions.
2- Estimation of water use efficiency and crop production.
3- Considering weather conditions for irrigation planning and supplemental irrigation.
4- Deficit irrigation evaluation.

Irrigation scheduling and calculation in the model is determined based on water balance in the crop root zone of soil on a daily basis. CROPWAT input data are the geographical location and elevation of the weather station in addition to the time series of meteorological parameters such as maximum and minimum temperatures, average relative humidity, wind speed at height of 2 m above the ground and sunshine hours. Moreover, FAO has presented all the climate input data based on geographical location in the CLIMWAT model. The outputs of CLIMWAT model can be used as an input for CROPWAT model. The most evapotranspiration in the region was 18.3 mm which is happened in the last 10 days of May. In this paper the detailed steps of the design of irrigation system is not presented and only a brief results of design is mentioned in Table 1.

Table 1. Drip Irrigation System components

Parameter	Value
Flow in each Dropper (Liter/hr)	8
Dropper distances in a row (m)	0.8
Laterals Flow Rate (Liter/Sec)	0.14
Distance between the Laterals (m)	1.83
Laterals length (m)	52
Manifold Flow Rate (Liter/Sec)	5
Manifold Length (m)	64

Irrigation interval is defined 3 days. In each day of irrigation operation, water enters the two of manifolds simultaneously, for example manifold 1 and 2 are operated on the first day, manifold 3 and 4 on the second day and manifold 5 and 6 on the third day. Since the crop water requirement varies in different months, the pump working hours are also variable in different months. In Table 2, the pump average working hours in each irrigation operation for different months are presented. The total hydraulic loss is 20 meters and the water should pump from depth of 10 meters below ground level from a well which is located in the north side of the field. Therefore the submersible pump must provide 30 meters head pressure to run the system properly. Since in each irrigation interval, only two manifolds are in operation, pump must provide flow rate of 400 cubic meters per day.

Table 2. Pump average working hours in each irrigation operation for different months

Month	Working Hours
September	3 (hr)
October	3 (hr)
November	2 (hr)
March	1 (hr)
April	5 (hr)
May	9 (hr)
June	10 (hr)
July	6 (hr)
August	4 (hr)

The catalogs of the German company (Lorentz) were used for Pumping system design. According to the pump curves, the PS 9k pump model can provide the head of 30 meters and flow rate of 400 cubic meters per day. The pump power is 7.5 kW which is supplied through 3 sets of tracking photovoltaic panels each produce 2.5 kW. Usable area of each panel is 1.5 square meters and the actual size of each array is 4.5 × 3.4 square meters. Photovoltaic panels are installed with a suitable distance from other equipments on the north side of the field.

3.2. Biogas System

Biofuels are being obtained from biomass resources. Biofuels include liquid ethanol, methanol, biodiesel and gas diesel fuels, such as hydrogen and methane. Wood and agricultural wastes, sugarcane, cereals and vegetable oils are the primary sources for biofuels. Today, most countries try to use these fuels to supply their energy demand. Microorganisms such as yeast, bacteria and fungi are capable of producing ethanol. Zymomonas mobilis is a kind of bacterium which is used for ethanol production. This bacterium can produce 1.9 moles ethanol from every mole of glucose (Savvides et al, 2000) (Skotnicki, 1981). Sugarcane and sugar beet molasses are used as a substrate of this bacterium (Savvides et al, 2000).
The technology for converting lingo-cellulosic biomass to ethanol includes these operating steps:

- Storing/Initial biomass processing: Grinding into small pieces in order to reducing the sizes and opening of the fibrous materials for further processing.
- Preprocessing: collection of lignin and cellulose Biopolymers and decomposition of structural components in order to improving accessibility to enzyme for increasing fermentation process
- Liquification: Hydrolysis of high viscous polysaccharides and producing a liquid of carbohydrate oligomers. This step can be done either by a basic/acidic reaction or with the help of enzymes as catalyst.
- Saccharification: Enzymatic hydrolysis of carbohydrate oligomers and producing monomeric fermentable sugars, mainly glucose (C6) and Xylose (C5).
- Separation of solid / liquid lignin fraction in order to use as fuel to generate electricity and heat (CHP).

- Evaporation: After Saccharification, Depending on the concentration of sugar, evaporation is needed to achieve a proper sugar level in order to producing ethanol at a minimum final concentration of 8.5 percent by volume in liquid. The evaporation step is necessary.

$$C1_2H_{22}O_{11} + H_2O \leftarrow C_6H_{12}O_6 + C_6H_{12}O_6$$
Sucrose Glucose Fructose

- Fermentation: Fermentation of C6 (glucose) and C5 (xylose) to ethanol.

$$C_6H_{12}O_6 \leftarrow C_2H_5OH + 2CO_2$$

The fermentation process takes three days and at a temperature between 25 to 30 degrees Celsius is done. The ethanol is then obtained by fractional distillation.
- Mechanical yeast separation by L/S separator: This process is usually done by centrifugation.
- Distillation: Increasing the concentration of ethanol which is produced from the fermentation of sugars and separation of crude ethanol.
- Correction: Increasing the ethanol concentration to 96% volume percentage.
- Dehydration: Ethanol dehydration is done by molecular tray in order to achieving the concentration of 99.9% volume percentage which is the characteristic of the alcohol fuel.
- Thermal conversion: In this step, the non-fermented organisms like lignin is collected and dewatered, and then the waste water treatment sludge is used to produce steam and electricity in CHP facilities.

All the fields of sugarcane in Iran are located in Khuzestan province. Sugarcane yield in this region is 47,000 kg per hectare in irrigated farms. Two hectares of sugar cane is cultivated in the farm. So, 94 tons of sugar has been produced in this farm which is used in biomass system for bioethanol production. According to the stoichiometric conversion of glucose to ethanol in the fermentation process, one mole of glucose converting to 2 moles ethanol and 2 moles of carbon dioxide which goes out of the system:

$$2C_6H_{12}O_2 \rightarrow 2C_2H_5OH + 2CO_2$$

Each gram of glucose is producing 0.51 gram of ethanol, theoretically. . Thus, 50% of glucose is converted into ethanol and 50% to the carbon dioxide. But practically, the result is lower (40 to 46%) and the remains are side products which consists of microorganisms and other chemical products. In this project, the synthesis of bio-ethanol was done by the Saccharomyces Cerevisiae yeast with using sugarcane molasses as a substrate. The optimum pH and temperature for yeast growth are 5.5 and 30 degrees Celsius, respectively. And the acidity was controlled by a normal concentration of NaOH and HCl. In this study, the ambient temperature was considered as the medium temperature which was about 25 to 30 degrees Celsius. The column reactor with retention time of 3 day was selected. Sugar concentration is a very important factor in the fermentation process and the high concentrations of substrate prevents the yeast growth and production, and disrupt metabolism of microorganisms. Several studies have reported that glucose concentrations between 5-25% (density) has a significant inhibitory effect, and in 40% (density) causes complete cessation of the activity of microorganisms (Becker, 2004) (Bekatorou, 2006).
To produce ethanol from bagasse, the fermentable sugar of each source must be determined at the beginning of process. In general, 0.46 kg ethanol is produced from fermentation of each kg of sugar.
Assuming that the density for ethanol is 0.789 kg/lit at 20 ° C, determining the amount of fermentable sugar in any cellulose or carbohydrate matter, the bioethanol which is produced from the material can also be determined.

Cellulose, hemicellulose and lignin are components of bagasse, which are about 12% of sugarcane. The amount of produced ethanol is calculated according to the presented equation. Table 3 shows that about 13.3 percent of the sugarcane is sucrose which is fermented directly and produce 0.69 liter per ton ethanol.

Table 3. The Sugarcane components weights ratio

Component	**Content (wt%)**
sucrose	13.30
Cellulose	4.77
Hemicellulose	4.53
Lignin	2.62
Reducing Sugars	0.62
Minerals	0.20
Impurities	1.79
Water	71.57
Dirt	0.60

According to the table 3, the fermentable sugar is 11280 kg and the sucrose is 12502 kg. The ethanol which is produced from bagasse and sucrose is 6576.42 liter and 8626.38 liter, respectively. So, about 15203 liters of ethanol were produced. Net calorific value of ethanol is 26.8 MJ/Kg and considering the density for ethanol (0.789 kg/liter), 11994.4 kg ethanol is produced in this field which can generate 321,450 MJ energy.

3.3. Wind Energy

The electricity which is needed for hydrogen production in the electrolysis process is generated by a wind turbine. Wind energy is generated by passing wind through the turbine blades and transferring the torque to the generator rotor. The power which is generated is related to the wind density, swept area by the blades, and the cube of wind speed.

As a general rule, wind generators are constructed where the wind speed is higher than 4.5 meters per second. The placement of wind power plant is usually determined based on the Wind Atlas/ encyclopedia. According to the Iran Wind Speed Encyclopedia, the city of Dezfoul has an average speed of 4.9 to 6.1 meters per second. So, the city is suitable for wind power plant construction to generate the electricity which is needed in the electrolysis process.

Air density in the study area is determined based on the average pressure and then, the turbine characteristics including blade length, the height, exergy and effective power of the turbine is calculated. The turbine efficiency factor in Iran is 0.33. Winds follow a general rule all over the world, but in terms of daily intensity and duration they are significantly different from place to place. Wind speed changes with height above sea level. The maximum and the average wind speed in the city of Dezfoul are about 12.5 meters per second (45 km/hr) and 5.8 meters per second, respectively.

The turbine power is the electrical energy produced at a specified time, which has a direct relationship with wind speed. The higher wind speed would lead to the greater potential of wind energy. The size of turbine is another factor which influences the power of the turbine, because by increasing the size of the turbine blades, the area or face of turbine is increased which increases rotation speed of the turbine blades and generates more energy. Therefore, taking into account the effects of wind speed and turbine face area, the generated power is calculated according to the equation (1) (Sahin and Aksakal, 1981).

$$P_{avail} = \frac{1}{2}.\rho.AV^3.C_P \quad (1)$$

Where P_{avail} is the generated power in watt, Cp, is the efficiency factor which is dependent on turbine

design, ρ, is the wind density in kilograms per cubic meter, A is the face area of turbine which is affected by wind, and V is the wind speed in meters per second.
Assuming air density as a constant (ρ=1) causes less than five percent error in the wind speed estimation (Hesseney, 1977). So, it is necessary that the Dezfoul air density is calculated considering the average summer temperature of the city and the height of 143 meters above sea level. Dezfoul air pressure is 1.54 bars and the average summer temperature is 49 degrees Celsius. According to the formula (2) air density is obtained 1.09.

$$P = \rho.g.h \qquad (2)$$

Efficiency factor is 0.33 and considering the input of fuel cell for electrolysis, the turbine exergy is 4.5. So, according to the formula (3) the actual turbine potential power is equivalent to 13.6 kilowatt.

$$P_{avail} = \frac{P_{actual}}{C} \qquad (3)$$

Generally, wind turbines which are used to generate electricity, in terms of power production, are divided into three categories: small, medium and large (Bansal et al, 2002) (Rai, 2000). In this study, the turbine type is determined by calculating the required energy for electrolysis process which produces hydrogen for the fuel cell. The use of large wind turbines in the farm because of the high cost of installation and low power consumption in the electrolysis process is not economically justified.
According to the equation (1), considering that the air density (1.09), the wind velocity (5.83 m/sec) in the city of Dezfoul, the coefficient of efficiency (0.33), and the amount of energy required for electrolysis process (KW), the face area and the length of blades which is the radius of the circular area are determined 126.6 square meter and 6.34 meter, respectively. The characteristics of the selected turbine are presented in table 4.

Table 4. The selected turbine characteristics

Parameter	Value
Blade length (m)	6.34
Turbine height (m)	40
Turbine Exergy (KW)	13.6
Turbine efficient Power (KW)	4.5
Coefficient of Efficiency	0.33

3.4. Cell fuel with electrical hydrogen resources

In design of the farm, a 4.5 kW electrolysis system for producing hydrogen, 1.5 kW hydrogen compressor, 1 cubic meter storage tank of hydrogen, a battery and DC / AC convertors were used. Hydrogen which is produced from water electrolysis would pass through the compressor. And the compressed hydrogen is stored in a cubic meter reservoir at a pressure of 10 bars to be used in times of need for producing energy by fuel cells. In the design of the fuel cell with electrical hydrogen resources, these components were used (Shiroodi et al, 2009):

- Battery: Sealed acid batteries with 12V and 100 Amper hours which are produced in Iran were used in this study.
- Convertor: The DC power produced by the modules is converted to AC power by three Sunny Boy convertors. This type of convertors has a small size, high efficiency and high speed in operation. The technical characteristics of the Sunny Boy convertors are presented in Table 5.

Table 5. The technical characteristics of the Sunny Boy convertors (Shiroodi et al, 2009)

Characteristic	Value
TYPE	3000
Max PV-Power	4100 wp
Max input Voltag	600 V
PV-Voltage MPPT	268 V 600 V
Max input current	12 A
Max AC Power	3000 W
Efficiency	95%
Nominal AC-Power	2600 W

Alkaline bipolar water electrolysis device which is used in this study is manufactured by German HT and is composed of 10 cells which their anode and cathode electrodes are made up of nickel and iron, respectively, and a diaphragm is situated between the electrodes. The electrical current and the maximum voltage of the device are 250 Ampere and 25 volt, respectively.

In the water electrolysis device, the electrical current passes through the solution much easier as the amount of ions in the solution increase. So, in order to increasing the ionic electrical conductivity in the alkaline water electrolysis device, potassium hydroxide (KOH) with a concentration of 28 to 30 percent by volume is used. The amount of hydrogen produced by electrolysis device is related to the water flow rate through the cells. This relationship is presented in the empirical equation (4) (Shiroodi et al, 2009).

$$Q= 4.12\times10^{-3} * I \qquad (4)$$

where, Q, is the water flow rate which passes through the cells in unit of cubic meters per hour, I, is the Nominal production capacity based on dry gas at temperature of zero degrees Centigrade and pressure of 1.013 bars for the 1 Nm^3/hr hydrogen gas. The oxygen gas which is produced in the process of water electrolysis has some impurities such as hydrogen, water vapor and electrolyte solution, is released into the atmosphere without any purification process. But the hydrogen gas which is used as the fuel of fuel cells is stored in high pressurized tank after purification.

The maximum permissible impurity with no risk of explosion in each gas is 2% oxygen in the hydrogen gas and 3% hydrogen in the oxygen gas. And if the values of impurities exceed the above thresholds, gases must immediately release to the atmosphere, and the system should be shut down as soon as possible. The characteristics of the alkaline electrolysis device model EV05/10 is presented in the table 6.

Table 6. The characteristics of the alkaline electrolysis device model EV05/10 (Shiroodi et al, 2009)

Parameter	Characteristic
Gas Producing Nominal capacity	1 Nm^3/hr H_2 0.5 Nm^3/hr O_2
Hydrogen Purity	99.9 %
Output pressure	10 mbar
Hydrogen flow Velocity after Compressor	4.4 m/s
Energy consumption for production of 1Nm^3/hr H_2	4.5 kWh
The Device Energy Requirement	3 Phase $v=380\pm5\%$ $\nu = 50HZ \pm 3\%$

In this study, a 10 bars pressurized hydrogen tank is used and the safety valve of the tank pressure is set to 12 bars.

PEM/Polymer fuel cell is selected because of its positive performance, high efficiency, ability to produce power quickly in the mode of standby, and performance at low temperatures (70 to 85° C). The Ernest equation which is the governing equation of the polymer fuel cell is as follows (G&G Technical Services Inc, 2013):

$$E = E_0 + (RT/2F)\ln[P\,H_2 / P\,H_2O] + (RT/2F)\ln[P\,O_2½] \quad (5)$$

The fuel cell used in the study is the Nexa 1200 model which is an ion exchange membrane (polymer) fuel cell with about 38 to 50 percent efficiency. The fuel cell lifespan prediction is 1500 hours of continuous operation or 500 times starting up and shutting down and its annual average electrical energy production is 102 kWh. The fuel cell characteristics are presented in Table 7.

Table 7. The Nexa 1200 Fuel Cell characteristics

Parameter	Characteristic
Voltage	22 to 50 volt
Fuel consumption	Hydrogen with more than 99.99% purity
Oxidizer	Ambient air
System Input Pressure	70 to 1720 kilo Pascal
Noise Pollution	72 dB at distance of 1 meter from the device
Warm Up Time	2 minutes
Fuel Consumption Rate	18.5 Standard Liter per minute
Heat Production	1650 Watt
Water Production	870 mliter per hour
Cooling System	Air Fan

So, the electrolysis device produces 1 Nm^3/hr hydrogen and 0.5 Nm^3/hr oxygen by using every 4.5 kWh energy which is produced by wind turbine. Then the hydrogen is used by fuel cell and about 870 liter per hour is produced which can be reused in electrolysis process. So, the fuel cell generates 102 kWh electrical powers.

3.5. Fuel cell with biological hydrogen resources

Biological fuel cells are a new type of fuel cells that can directly convert biochemical energy into electricity. The driving force in this kind of cells is the oxidation and reduction reactions of carbohydrate material such as glucose which is mixed with ethanol. Microorganisms or enzymes are used as biological catalysts in these reactions. The functioning principles of the cells are like the chemical fuel cells, and the main differences between them are the type of catalyst application, and operation conditions. In Biological fuel cells, a microorganism or an enzyme is used as a catalyst which replaces by metal in the chemical fuel cells. Generally, there are two types of biological fuel cells:

- Direct: In the direct type, cell contains electrodes which are in direct contact with biochemical factors and are involved in the oxidation and reduction reactions. The actual power which is generated in the direct cells is equal to one tenth to one hundredth of the indirect cells. The process in these type of cells, is limited to the reactions between the biocatalyst and electrode.
- Indirect: In this type of cells, bacteria or enzymes are used to convert biological fuels into high or low (liquid or gas) molecular weight compounds. These biological materials participate in a normal electrochemical process. The obtained products of a microbiological reactor may be hydrogen, ammonia or oxygen which is the advantageous characteristics of these cells that make the use of wastes such as carbon dioxide and human sewage possible (www.farahan1989.blogfa.com). In Table 8, The Bioreactor size based on synthesis rate of bio-hydrogen is presented.

Table 8. The Bioreactor Size based on synthesis rate of bio-hydrogen (Naeempour et al, 2009)

$BioH_2$ system	H_2 synthesis rate (mmol $H_2(1\times h)$)[a]	Size of bioreactor(liter)
Photo fermentation	0.16	3.74×10^5

Various types of microorganisms are used in hydrogen production. In this study, the Rhodobacter Sphaeroides was used as microorganism which is symbiotic with clover. Considering the farm area and systems designing standards, each gram of the Rhodobacter Sphaeroides bacterium produces about 0.16 m mol hydrogen by light fermentation. So in order to producing 2.5 kW power by the fuel cell, the bioreactor volume is required to be 374 m^3 to produce the amount of needed hydrogen. From each square meter of clover planting in the farm, an average of 10 to 30 grams symbiotic bacteria will be available. The results of the electrical energy produced by the fuel cell are presented in Table 9.

Table 9. The results of the electrical energy produced by the Fuel Cell

Parameter	Amount
Clover Planted Area (m^2)	108.5
The amount of clover symbiotic bacteria (gr)	2170
Fuel Cell Output Power (kWh)	5425

Therefore, the total power produced by electrical and biological hydrogen source fuel cells is 5527 kWh.

4. Conclusion

Energy farm is the symbol of using renewable energies. Designing these kind of farm in comparison with many other traditional farms, is an efficient way of introducing importance and possibilities of renewable energies application and helps to increase the farmers knowledge practically. All the energy which is used in this farm is produced from renewable resources and all the local potentials of renewable sources were considered for producing a clean and sustainable energy. In each agricultural season (1 year for sugarcane) 12260 liters of ethanol will be produced in the biofuel system. The energy produced by the fuel cell system is 5527 kWh, that 102 kWh of it is produced from electrical hydrogen sources and 5425 Kwh of it is produced from biological hydrogen sources which are all of the clover symbiotic microorganisms. Ultimately, the optimal use of land, water and free sources of energy could be feasible by implementing energy farm.

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