Power Plants Proposal

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Generating cheap and clean energy by making a plant microbial fuel cell using cheap materials

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Abstract:

Egypt faces a lot of grand challenges, nowadays, which led to a great corruption in the economical, educational and health issues in the community. The energy challenge has become the most effective one in this century that led to many global conflicts. So, our project has started a way of integration between generating green energy and improving environment in order to solve many challenges such as pollution and lack of energy. Our project has connected generating energy using green plants. The idea of our project is making a natural electro-biochemical fuel cell depending on a natural resource in the environment. Specifically, we will rely on the photosynthesis process of the green plants using the wet agricultural soil, the naturally existing living organisms and other simple materials that could be found anywhere easily. Electricity is generated 24 hours a day without harming the plants or the environment achieving high-efficiency and low-cost. These are the designing requirements for our prototype.

Introduction:

Many solutions for the lack of energy have emerged during the last decade. At first we worked on a project to increase the efficiency of generating energy using gravity. It sounded a great solution as it is renewable and very cheap. Yet, we found out that this idea is not applicable as its efficiency was relatively low. Thus, we decided on another idea which deals with plants. What makes this project unique is that it achieves our design requirements which are low-cost and high-efficiency. It also integrates being green and generating energy to solve energy, environmental corruption and pollution as grand challenges in Egypt using the wet wide propagated agricultural soil in Egypt (such as that of the rice). Our project depends on the natural photosynthesis process that plant makes, but how? As a result of the sunlight plants secrete organic matter (glucose), the plant only consumes 40 % to grow, and the rest of the organic matter is released into the soil. This organic matter could be a green, clean and sustainable source of energy (electricity). As the plant performs photosynthesis process, it takes up carbon dioxide (CO_2) and gives oxygen (O_2) back to the air. The plant releases the rest of the organic matter into the soil through the roots. Naturally occurring micro-organisms (bacteria) that present naturally in the soil take in the organic matter (glucose ($C_6H_{12}O_6$)) and produce a proton H^+ and an electron e^-. A Proton Exchange Membrane (PEM) (a Gelatin membrane in our project) would be placed in the soil and at its two sides there are an anode and a cathode. The proton (H^+) can pass through the membrane to the cathode, but the electron (e^-) cannot. The electron (e^-) passes from the anode through a circuit to the cathode to be reunited with the proton H^+ to form water.

Review of literature:

At first the plant fuel cells were made following the tubular system strategy (Helder, 2012), also according to (Plant-e, 2013) the used materials in making the proton exchange membrane were very expensive (e.g. Nafion). The membranes were made from Nafion and other expensive materials (Al, 2012). Also as was stated in *Instructables* (www.instructables.com) the used way in making the membrane was also the tubular that wasn't efficient, but we used very cheap materials such as Gelatin using more efficient strategies in making a more efficient system, which is the flat system.

Materials & Methods:

Materials
Copper plate (Cathode).
Zinc plate (Anode).
Window's metal screen (0.25m²).
Glass Container (25cm * 25cm * 25cm).
Powder Gelatin (Proton Exchange Membrane). (250 gram).
Crocodile wires.
Green Plant (Rice or Sugar cane).
Dry glue (250 gram).
Multimeter.
Salt (100gram).

	Methods
1	Using a glass container
2	Putting the wet plant (rice) in the container with the soil and the water above and under it.
3	Preparing the proton exchange membrane from gelatin with some salt by using the second container as a mold.
4	Immersing anode covered with window's metal screen in the soil and the water touching the plant roots.
5	Putting the cathode in the container behind the proton exchange membrane.
6	Connecting the anode and the cathode plates with crocodile wires.
7	Connect the other ends of the crocodile wire to a multimeter.
*	Proton exchange membrane was made by boiling it in water then putting it in the refrigerator to freeze. Remember to expose the plant to sunlight.

	Design Requirements Testing Steps (Test Plan)
1	Efficiency: • Record the readings of the multimeter using our flat system to measure the potential difference. • Compare to the standard tubular system efficiency.
2	Cost: • Comparing between the gelatin proton exchange membrane and the Nafion in cost concerning efficiency. • Comparing between the cost of the Watt in our project and in the standard one.

Results:

The Efficiency design requirement:

Observations and readings:

Potential Difference (Average) = 2.02 (±0.1) Volt

Power Density = (3.5 (±0.1) W/m²)

P = 350 (±1) W/100m² per hour

(There is 8766 hours per year)

P = 3068.1 (±1) KW per year per 100m²

The potential difference using the flat system = 2.02 (±0.1) Volt

The potential difference using the tubular system = 245 Millivolt = 0.245 Volt

The Cost design requirement:

1) Observations and Calculations:

The standard cost of Nafion PEM for 5m²

= [€300, €1100]

The cost of our gelatin PEM for 5m² = [€3, €7]

2) Observations and Calculations:

The cost of the Kilowatt in our project compared to the standard is:

$\frac{15}{3068} : \frac{750}{30680}$ = 0.0049: 0.0244 = 1: 5

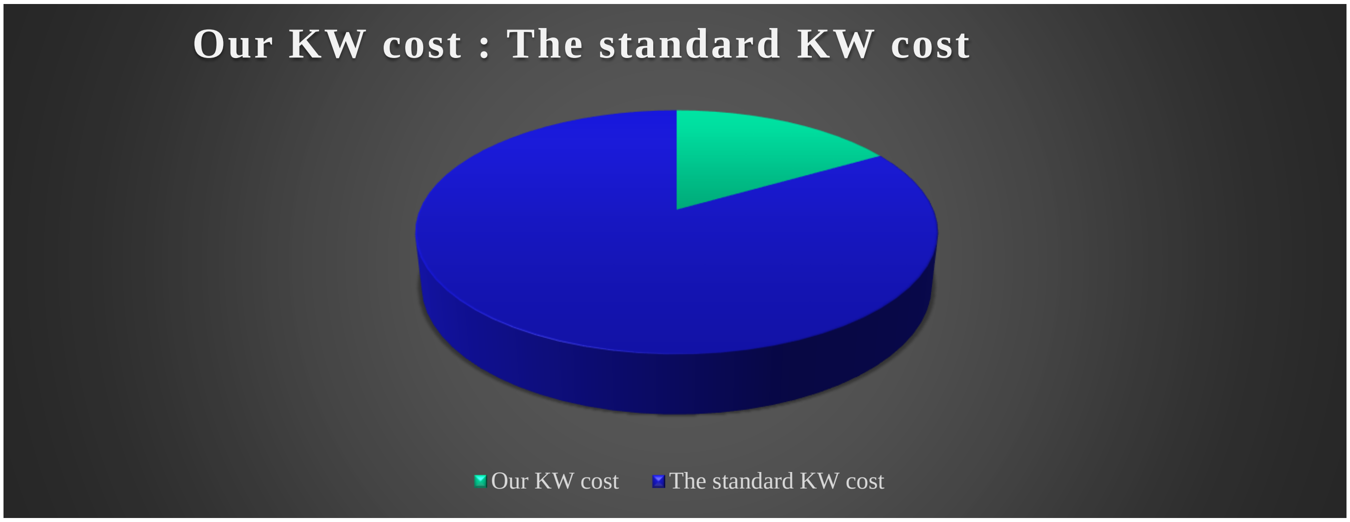

Figure 1: Our KW cost to the standard one

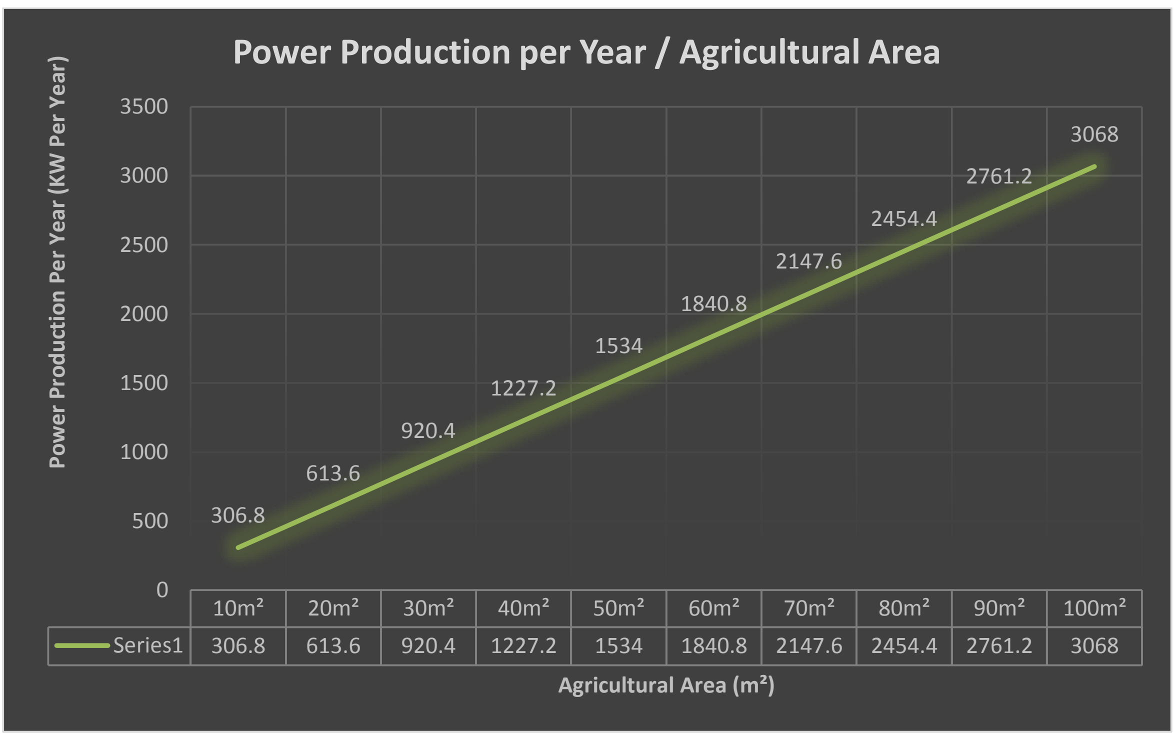

Figure 2: Production per year/ agricultural area

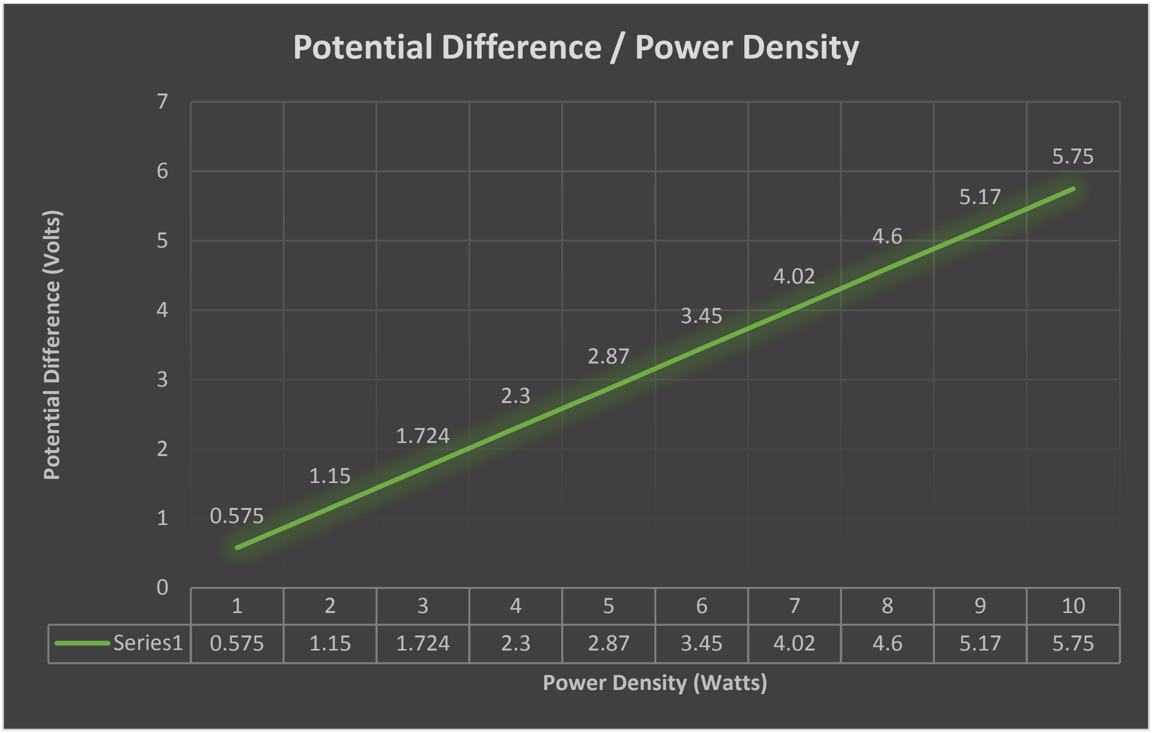

Figure 3: Potential difference/ power density

Figure 4: The prototype

Discussion:

The Plant & the Soil:

The plant is the main part as it is the energy source in our project. We chose the rice and the sugar cane (As to make the integration between the agricultural seasons). Since rice and sugar cane are planted in wet soil then they will offer for us the perfect working environment to work in offering the perfect conditions for the anode and the electrolyte to work in. Also, sugar cane has the highest photosynthetic efficiency (As 8% of light energy is converted into chemical energy during photosynthesis). The plant's soil is also a very important part in our project as the soil is the source of the micro-living organisms and the bacteria (microbes) that will do the process of generating energy, also the soil is the shelter of storing the extra organic matter secreted by the plant which represent about 70% of the organic matter (energy) that the plant made during photosynthesis process.

The Proton Exchange Membrane:

PEM is a semipermeable membrane designed to conduct protons while being impermeable to electrons. One of the most common and commercially available PEM materials is the fluoropolymer (PFSA) Nafion but Nafion is not what we are using in our project, but why? Nafion is relatively expensive also it is not available in Egypt so it is not a good choice for constructing a solution for the energy problem or for achieving the low-cost design requirement. Our PEM is made of gelatin with salt (To increase the efficiency). It consists from very simple and cheap materials and you can make it easily. This Proton Exchange Membrane allowed us to achieve the low-cost design requirement and also to maintain as possible the high-efficiency requirement as the cost of the Nafion ranges from 150 euros to 1100 euros, and the cost of our gelatin membrane is less than 10 euros and as it allows us to have the largest surface area with the least separating distance (The flat system). We achieved the ratio of 5: 625 =1: 125 concerning that the resistance increased by the ratio of 0.2: 0.02 = 10: 1

The Electrodes:

We have made experiments to make sure of using the best anode as it is an important .axis in any fuel cell. We used Copper and Zinc. This helped us in achieving the high-efficiency design requirement. Also, some researches state that using graphite fiber as an anode will be better, but we cared for the cost.

Microbes (Micro-living organisms):

Microbes are thriving throughout virtually all soils, sediments, and streams on the planet. “Electrogenic” microbes are able to “breathe” metal compounds much like humans and other organisms breathe oxygen. They have unique abilities that enable them to release electrons onto metal compounds.

- (aka *Shewanella*): *Shewanella* species can be found almost everywhere on earth, from mountain soils to ocean sediments. They have an ability to metabolize a wide variety of elements. These abilities make *Shewanella* an ideal bacterium for bioremediation processes.
- (aka *Geobacter*): Known as the “iron-breather”, *Geobacter* species have the ability to “inhale” iron compounds and use them in a way similar to the way humans use oxygen. In fact, they prefer to live in environments where there is no oxygen, such as deep underground or within ocean sediments. *Geobacter* species have the ability to consume many environmental pollutants, including petroleum and Uranium and have been used in many soil and water bioremediation efforts.

The prototype design:

PMFCs generate maximum power when subjected to an external resistance that is equal to its own internal resistance. This internal resistance is a function of the ability of ions to diffuse through the PMFC media from anode to cathode. The lower this internal resistance, the more power the PMFC will produce. There are many ways to decrease this resistance, such as adding electrolytes (salts) to the media, and shortening the distance between the anode and cathode.

$P = V^2/R$ P = Power (Watts)

V = Voltage (Volts) R = Resistance (Ohms)

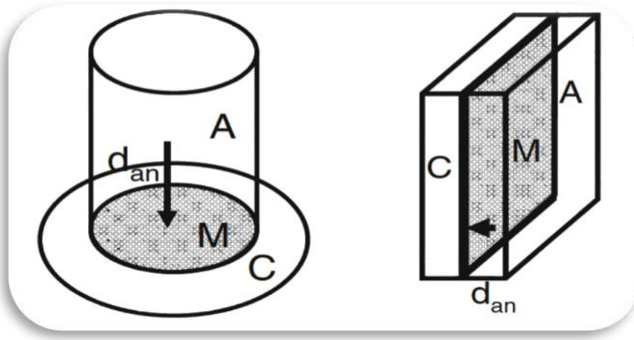

Figure 5: Tubular and flat system

So our design must offer the least distance between the anode and the cathode and the largest surface area at the same time so we prepared the Proton Exchange Membrane as a slice with large surface area and relatively thin to offer the highest possible efficiency that our membrane could achieve. Also using the flat plate design instead of the tubular design offers the least distance between the electrodes and the largest surface area. The flat system increased the efficiency with the ratio of 2.02V:0.245V = 8.245: 1 compared to the tubular system. Moreover, the design focuses on the bottom part as it is exposed to the roots. Also, the window's metal screen to collect the largest No. of electrons.

The Organic Matter:

Organic matter is matter composed of organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment. Organic molecules can also be made by chemical reactions that don't involve life. Basic structures are created from cellulose, tannin, cutin, and lignin, along with other various proteins, lipids, and carbohydrates.

The organic matter is heterogeneous and very complex. Generally, organic matter, in terms of weight, is:

- 45-55% carbon
- 35-45% oxygen
- 3-5% hydrogen
- 1-4% nitrogen

Conclusion:

Our project makes important and effective changes in the PMFC (Plant Microbial Fuel Cell) by reducing the cost with a huge ratio. Using very simple and cheap materials that are easy to make at your home. Maintaining the highest efficiency possible after decreasing the cost. By using new techniques and factors to produce 3068 KW per year per 100m² which will offer about 110% (3068/**2800**) of the average household consumption per year in Egypt. Also, our Kilowatt's cost is 1/5 of the standard Kilowatt's cost.

Recommendations:

1. Increase the efficiency of the electrodes by using some graphite products such as graphite paper or graphite fiber.

2. Making a strong insulating frame (backbone) for the Proton Exchange Membrane to make it stronger.

3. Increasing the area of the prototype to 1m² in order to be easier in obtaining results and readings.

4. Using wireless electricity transferring technology in order to be easier and more flexible to suit the agricultural soil environment.

5. Suiting the agricultural environment by finding solutions for the natural factors or phenomena that could harm the process of generating energy.

6. Using power inverter, batteries and step-up to suit the domestic usage.

References:

Journals:

- Helder et al. Biotechnology for Biofuels 2012, 5:70
  www.biotechnologyforbiofuels.com/content/5/1/70

- Sustainable and Green Growth: A Main Pillar of the Egyptian National Competitiveness Strategy Helmy Abouleish, Chair, ENCC Cairo, 23rd January 2011 Egypt Green Economy National Initiative

Websites:

- Home - Fuel Cell Energy. (n.d.). Retrieved March 17, 2015, from www.fuelcellenergy.com/

- Energy.gov. (n.d.). Retrieved March 15, 2015, from *http://energy.gov/eere/fuelcells/fuel-cells*

- Plant-e.com Home. (n.d.). Retrieved March 8, 2015, from *http://plant-e.com/*

- Technology. (n.d.). Retrieved March 13, 2015, from *http://plant-e.com/technology.html*

- Prepare The Proton Exchange Membrane. (n.d.). Retrieved March 29, 2015, from *www.instructables.com/id/Microbial-Fuel-Cell-Of-Science/step2/Prepare-The-Proton-Exchange-Membrane*/

- Microbial Fuel Cell Of Science!!! (n.d.). Retrieved March 30, 2015, from *http://www.instructables.com/id/Microbial-Fuel-Cell-Of-Science/*

Books:

- Reece, J., & Urry, L. (n.d.). Campbell biology (Tenth ed.).

- Kelter, P., & Zumdahl, S. (2007). Chemistry, seventh edition, Zumdahl. Boston: Houghton Mifflin.