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Application of Aloe Vera-derived Plant-based Cell in Powering Wireless IoT devices in a Smart Greenhouse

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Abstract

The electrical energy represents the harvested from the living plants which can be used as a renewable energy for powering wireless devices in remote areas where recharging or replacing the battery is a difficult task. Therefore, harvesting electrical energy from living plants in remote areas such as in farms or forest areas can be an ideal source of energy as these areas are rich with living plants. The present paper proposes a design of a power management circuit that can harness, store and manage the electrical energy which is harvested from the leaves of (Aloe Vera) plants to trigger a transmitter load to power a remote sensor. In the present paper, we have proposed a power management circuit, which can harvest the electrical energy from the Aloe Vera plants and converts the plants into a plant-based cell (PBC) to activate a remote sensor via a wireless transmission .The power management circuit consists of two sections namely; an energy storage system that acts as an energy storage reservoir to store the energy harvested from the plants as well as a voltage regulation system which is used to boost and manage the energy in accordance to a load operation.

Keywords:

Pawa plant, Renewable energy, weak energy, Aloe Vera, electrical energy , IoT

INTRODUCTION

The extensive use of burning fossil fuels raises the level of carbon dioxide in the atmosphere thus resulting in serious greenhouse effects. The greenhouse gases gradually increase the temperature of the Earth's surface and therefore bring us a warmer atmosphere and collapsing global environment. There is no doubt that climate change is upon us, therefore the next appropriate action is to minimize those long-term effects. Increasing the use of renewable energy has been encouraged by government in many countries, because this technology provides an excellent opportunity for the mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy Sources Advancement of technology in the 21st century has created a series of low power consumption and smaller size consumer electronics. This phenomenon had opened up the opportunity

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for the development of energy harvesting technique from low power energy sources such as from the vibration via piezoelectric materials, bioenergy from organic compounds via microbial fuel cell, radio frequency (RF) signal via RF power harvester, thermal energy via thermo-electric generator (TEG) and light energy via solar photovoltaic cell. These technologies had been well known and used to harvest micro-energy. Hence, apart from these existing technologies, this research would like to introduce the usage of living plants as another new renewable energy source to harvest micro-energy. Certain plants can produce a continuous small amount of electrical power at both day and night, unlike solar power, which is only functional in the presence of light. This new source of energy from plants is renewable, pollution free and sustainable as long as the plant is alive. Plants are sensitive to light due to its photoreceptors, which can be categorized as phytochromes, Living-plants have been proven to have a potential for renewable energy source by embedding pairs of electrodes into it to allow flow of ions and hence generate electricity. Multiple tests using different type of electrodes and plants suggested that voltages are produced to greater or lesser extents where combination of copper (Cu)-zinc (Zn) and Aloe Vera produces the highest voltage output. To optimize the power output from the plant, a comprehensive knowledge regarding the mechanisms of energy generation is necessary. Initial hypothesis inferred this from electrochemistry process. Therefore, the presence of trace metals from the electrodes using Flame Atomic Absorption Spectroscopy (FAAS) was investigated in the plant to gain insight into the origin of the energy production. To further justify the stated hypothesis, comparison of trace metals concentration in electrodes immersed Aloe Vera between opened and closed circuit is also investigated. The obtained result confirmed that the electrochemistry process is responsible for the mechanism of the energy production from living plant.

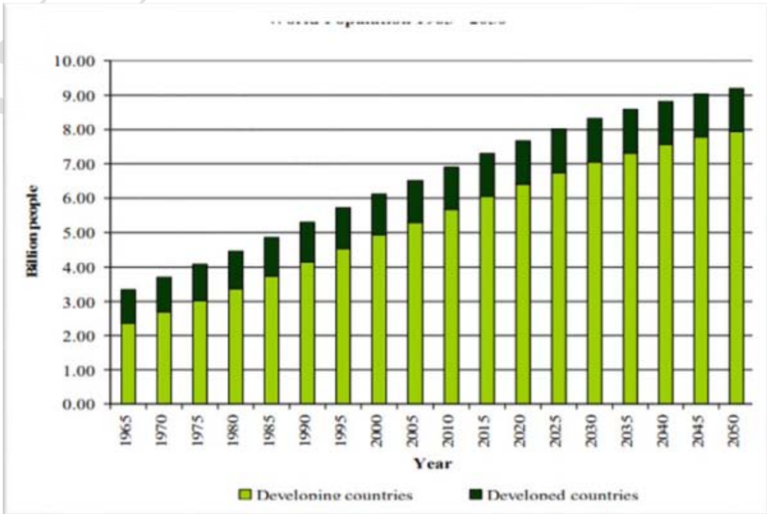
1.1 Problem Statement

The smart greenhouse market is expected to grow at a CAGR* of 9.2% from 2020 to 2025. [1]

1.2 Problem Statement

● The major drivers for the growth of the market are the growing demand for food owing to continuously increasing global population[2] and the surging adoption of indoor farming in urban areas[1]

● The primary problem limiting the growth of smart greenhouses is the dependence of IoT* on billions of batteries to power the sensors critical to its operation[3].



2.1 Proposed Solution - Pawa Plant

- We imagine a world where no one is hungry and where the technology to produce this food doesn't depend on batteries that otherwise could not be deployed

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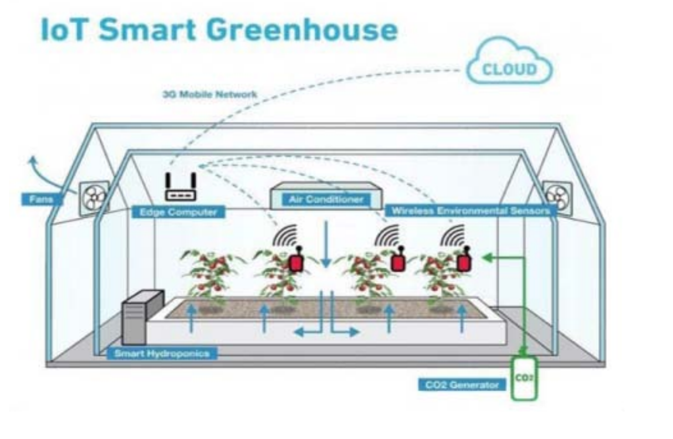
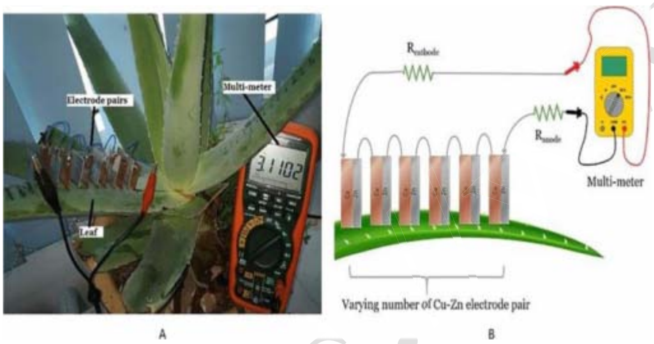
2.2 Proposed Solution - Pawa Plant

● We hope to do this through a technology that allows urban farmers to monitor their crops, day- in, day-out, even at night,



with wireless IoT devices; without having to worry about battery replacements.

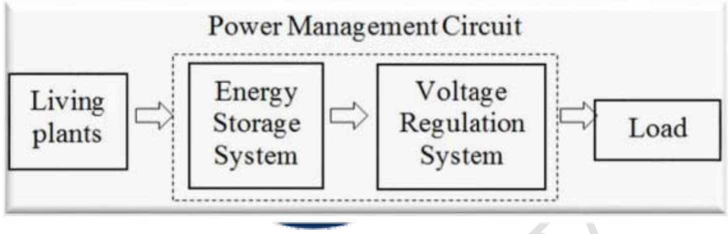
● This is because we identified that Aloe Vera can produce electrical energy in conjunction with special metals, and that this electrical energy can be boosted to power these IoT devices without the need for additional alkaline or Li-ion batteries[4].



3. Key Points of Differentiation

● We chose the Aloe Vera because it's an extremely robust plant, and the electrical supply happens throughout the day unlike solar panels (only during the day) or wind turbines (only above a critical wind speed).

● Solar power might generate more power on a small surface but plant electricity does not compete with the natural land use and promotes green in urban environments.



4.1 Technical Feasibility

● A wireless transmission often needs only intermittent data acquisition and periodical transmission of data to a receiver; thus, a continuous supply of power is not required.

● A power management circuit is required to store and channelize sufficient energy needed to operate the wireless devices at an appropriate interval.

Fig 1. Block Diagram of the Proposed Plant-based Cell Greenhouse System

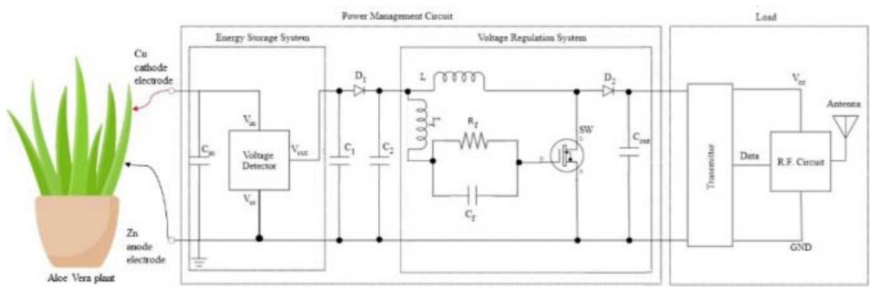
4.2 Technical Feasibility

● The Plant-based cell greenhouse system will consist of an energy storage circuit that acts

as an energy storage reservoir to store the energy harvested from the Aloe Vera plants

● A voltage regulation and monitoring circuit will ensure that the IoT devices always get the power that they need to operate effectively.

Fig 2. Schematic Diagram of the Proposed Plant-based Cell Greenhouse System



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4.3 Technical Feasibility

Experimental results show that the electrical energy harvested from the Aloe Vera under a specific setup condition can produce an output of 3.49 V and 1.1 mA[4].

The number of leaves connected in parallel connection.	Voltage (V)	Current (uA)	Power (uW)
1 (first leaf)	3.4670	107.07	371.21
2	3.4883	167.76	585.20
3	3.4882	224.82	784.22
4	3.4875	271.15	945.64
5	3.4858	335.44	1169.28
6	3.4978	385.08	1346.93
7	3.4747	422.22	1467.09
8	3.4850	524.18	1826.77
9	3.4710	558.40	1938.21
10	3.4867	613.90	2140.49
11	3.4798	686.60	2389.23
12	3.4652	720.90	2498.06
13	3.4545	781.18	2698.59
14	3.4978	823.58	2880.72
15	3.4876	856.75	2988.00
16	3.4897	890.81	3108.66
17	3.4864	920.96	3210.83
18	3.4805	957.17	3331.43
19	3.4990	981.05	3432.69
20	3.4981	1108.51	3877.68

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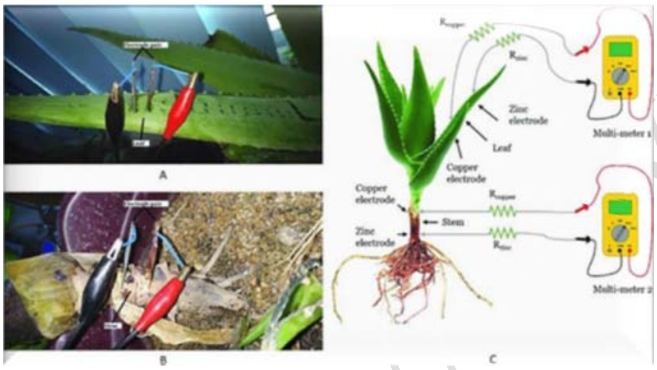
Table 1. Voltage measured when varying numbers of



electrode-pairs connected in series into a leaf.

4.4 Technical Feasibility

● The harvested energy is being channeled to the power management circuit which can boost the voltage to 10.9 V under no load condition.

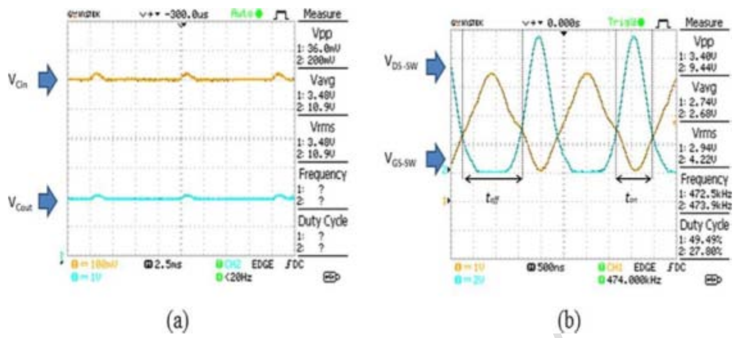


Fig 3. Performance characteristic of the self-oscillating boost converter.

(a) shows the output voltage VCout and VCin of the power management circuit

(b) shows the switching characteristic of the SW switch

4.5 Technical Feasibility

● The harvested energy from the Aloe Vera plants boosted by the power management circuit will be able to produce enough electrical output to power a typical wireless sensor and data logging equipment ((including Schneider's Accutech* and Data Logger** respectively).

*Accutech = Schneider Electric's battery-powered wireless sensor networks

**Data Logger = Schneider Electric's ultra low-power, autonomous wireless telemetry device.

5.1 Economic Feasibility

● According to the FAO*, the increasing demand for sustainable food has led to over 200 million people farming in urban environments worldwide[5-6].

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● The Plant-based Cell Greenhouse System benefits these farmers as they are able to leverage IoT sensors with far cheaper energy overheads; getting healthier and more fruitful crops for less operating costs.

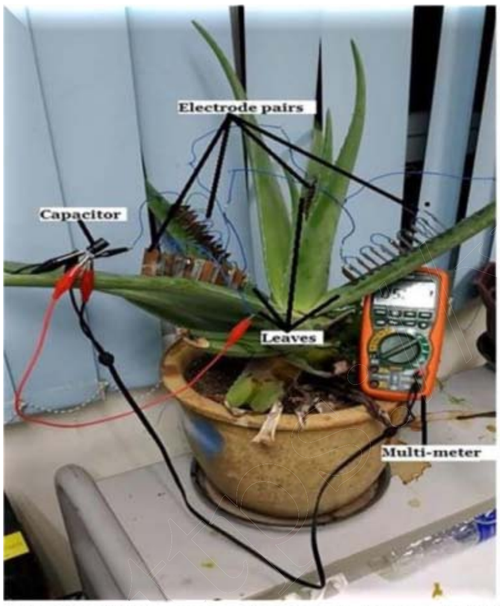
*FAO = Food and Agriculture Organization

5.2 Economic Feasibility

● The system is intended to be simple and accessible, so that every urban farmer can own and leverage this technology and see the benefits instantly.

● The more of the systems that are deployed, the more we reduce world hunger and increase local financial sustainability. But also, the healthier our planet and its inhabitants become.

*FAO = Food and Agriculture Organization



6. Operational Availability

● Smart greenhouses anywhere in the world where measurements of temperature, humidity, soil, air or water quality are needed are suited for this technology.

● We imagine the rooftops of such households having this system for powering the IoT devices.

● A long-range low-power data transmission will be achieved by a wireless Ecostruxure* connection, but other low-power consuming options are possible as well.

*Ecostruxure = Schneider Electric's IoT-enabled architecture and platform with connected products like sensors

7.1 Scalability

● The Plant-based Cell System will be developed as a modular system which can be used as energy building blocks.

● The modules will optimize the conditions for electricity production and make it possible to generate electricity everywhere with the help of plants.

7.2 Scalability

- For example, we can already light LED lights and supply sensors or other low power consumption devices with power from a single module.

- The modules can further be scaled up to be able to power up at least half of buildings for other IoT- enabled

applications like lighting and even charging of mobile devices.

8. Sourcing

- Aloe Vera is among the highly commercial plant products that grow in Africa[7]

- For example, Farmers in the Baringo County of Kenya are tapping into the farming of Aloe Vera as the demand for the plant rises following its high economic value particularly in foreign markets[7].

- This makes Africa a perfect market for this technology.

- Sourcing for the key element of the technology won't be a challenge

CONCLUSION

The plant base cell (PBC) has been presented as a new electrical energy to storage and new source for the power low and the power consumption devices such as a transmitter. The Plant-based Cell System will be developed as a modular system which can be used as energy building blocks.

The modules will optimize the conditions for electricity production and make it possible to generate electricity everywhere with the help of plants.The PBC constitutes of a power management system that is connected to Cu-Zn electrode pairs which are embedded into the leaves of the Aloe Vera plants. The proposed power management system can perform a fully autonomous operation to harvest the electrical energy from the Aloe Vera plants to trigger a transmitter load to send signal periodically to the temperature sensor. This has been confirmed by performing the experiment under a real-life condition. The designed power management circuit, which consists of an energy storage system and a voltage regulation system, can store the minute energy harvested from the Aloe Vera plants and boost them into sufficient energy to power a transmitter load. The transmitter load is proven to be in operation as it sends an intermittent signal to the receiver circuit to activate a remote sensor to measure the surrounding temperature and humidity.

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