



Sustainable Technology: Power Plant by Living Plant

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Abstract

*The demand for electricity is critical to the development of every country, emphasizing the global need for renewable, efficient, and sustainable energy sources. An innovative approach to green energy involves the use of living plants to generate electricity without causing harm to them. Living plants can produce measurable voltages capable of powering small devices, such as LED bulbs, thereby functioning as natural green generators. This paper presents a sustainable technology based on biological processes that not only generates electricity but also offers ecological benefits such as insulation, water storage, and biodiversity support. The technology harnesses electrons released by bacteria living around plant roots during the decomposition of organic matter excreted by the plant. These electrons are captured using inert electrodes placed in the soil, generating electricity without affecting plant growth. An experiment using *Epipremnum aureum* (money plant), copper and zinc electrodes, and simple circuitry demonstrated voltage outputs between 1.8–2.4 volts, with a peak of 2.45 volts and potential reaching up to 3 volts, along with sufficient current to intermittently power LED bulbs. Compared to thermal and nuclear power systems, this plant-based nano power plant offers a clean, low-cost, and sustainable energy alternative aligned with environmental goals.*

Keywords: Energy Sources, Sustainable Energy Systems, Energy Efficiency in Utilization, Power Generation Technologies, Carbon Footprint Reduction, Eco-friendly.

Introduction

Growing global efforts toward sustainable development have prompted nations to invest heavily in renewable energy infrastructure, aiming to reduce reliance on fossil fuels and lessen the effects of climate change. The pressing need to combat the environmental consequences of excessive fossil fuel consumption has highlighted the relevance of alternative energy systems. The expansion of renewable energy technologies is largely driven by three key factors: improving energy security, lowering overall economic costs, and reducing greenhouse gas emissions¹. In recent years, renewable energy solutions have received substantial attention, particularly those that leverage natural biological mechanisms for power generation. One promising strategy is the utilization of living plants as a source of bioenergy. Through photosynthesis, plants capture solar energy and convert it into chemical energy, storing carbon dioxide in the form of carbohydrates. This biological process not only fuels plant growth but also plays a vital role in global carbon cycling².

The proportion of carbon transferred from leaves to roots after photosynthesis can reach as high as 60%, depending on factors such as plant type, developmental stage, and surrounding environmental conditions. Once in the roots, a portion of this carbon is released into the soil in the form of various organic

substances, including simple sugars, organic acids, complex carbohydrates, enzymes, and gases such as ethylene and carbon dioxide. This collection of processes, known as plant rhizodeposition, results in the formation of rhizo deposits³. These rhizo deposits serve as a renewable bioenergy substrate in plant-microbial fuel cells (plant-MFCs), a technology that converts biochemical energy into electrical energy. Rhizodeposition may represent 40% or more of the total carbon assimilated through photosynthesis by the plant., highlighting the significant potential of this technology to generate sustainable energy. As the world continues to seek innovative solutions to energy and environmental challenges, plant-MFCs represent a promising avenue for integrating renewable energy production with ecological conservation⁴.

Existing Power Plants: Thermal power plant: Heat energy is converted into electrical energy using thermal power plant. They offer several advantages, including relatively low fuel costs and the ability to generate energy in almost any geographic location. The operation and maintenance of these plants are generally straightforward, making them a widely understood and manageable technology⁵.

However, there are significant drawbacks associated with thermal power plants. One of the primary concerns is the substantial emission of carbon dioxide (CO₂) and other

pollutants, which contribute to environmental degradation and change in climate. Additionally, these plants typically exhibit low overall efficiency compared to other energy generation methods. Another issue is the high demand for lubricating oil, which not only adds to operational costs but also presents environmental hazards if not managed properly. These challenges highlight the need for alternative, cleaner energy sources to mitigate the negative impacts associated with thermal power generation⁶.

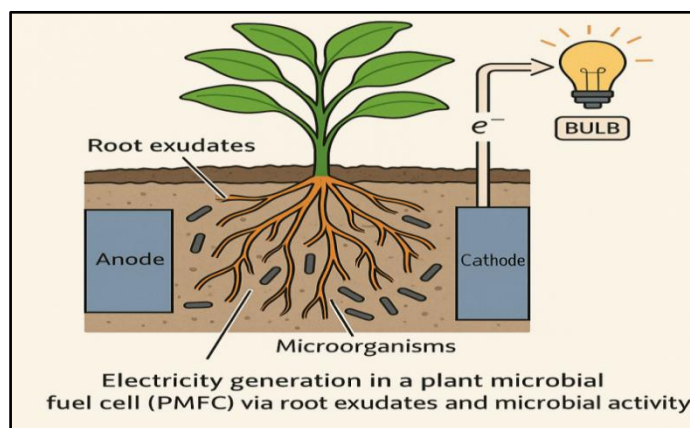


Figure-1: Illustration of a plant-powered system generating electricity to light a bulb through microbial fuel cell action.

Nuclear power plant: Nuclear power plants generate electrical energy through nuclear reactions. Such plants offer multiple benefits, including comparatively low operational expenses and significantly reduced greenhouse gas emissions relative to conventional fossil fuel power systems. Additionally, current estimates suggest that, based on today's consumption rates, there is sufficient uranium to fuel nuclear power plants for approximately 80 years⁷.

However, there are significant disadvantages to nuclear energy. A major challenge associated with nuclear energy is the safe management of radioactive waste, which presents significant long-term risks to both the environment and public health. The catastrophic consequences of nuclear accidents, such as the Chernobyl disaster, continue to underscore the potential dangers of nuclear radiation exposure. In addition, nuclear power facilities demand very high upfront capital expenditure, resulting in considerable construction and maintenance costs.. Another critical challenge is the limited availability of uranium, which is a scarce resource found in only a few countries, unlike fossil fuels that are more widely distributed globally. This scarcity of uranium adds an element of resource dependency and geopolitical concern to nuclear energy production⁸.

Coal-fired power station: Coal-based power plants are thermal generation facilities that utilize coal combustion to produce electrical energy. These plants account for over a third of the world's electricity generation. However, they are also major contributors to air pollution, which is linked to a substantial

number of premature deaths each year. The advantages of coal-fired power stations include the vast global reserves of coal, the non-intermittent nature of coal as an energy source, its compatibility with other energy systems, and relatively low capital investment requirements compared to some other forms of power generation⁹.

However, there are several critical disadvantages associated with coal-fired power stations. Burning coal emits numerous hazardous pollutants into the air, such as carbon monoxide, sulfur dioxide, and particulate matter, all of which exacerbate air pollution and present significant health hazards. Studies have shown that individuals living or working near coal plants are at higher risk of developing respiratory illnesses, such as asthma and lung cancer. Additionally, coal contains trace amounts of naturally occurring radioactive materials, adding to the environmental and health hazards. The coal mining and utilization also have significant ecological impacts, including habitat destruction for plants and animals. Furthermore, coal is a non-renewable resource, meaning that its use is unsustainable in the long term. In cases where coal deposits are located in inhabited areas, mining can disrupt communities and render areas uninhabitable. The cumulative environmental and health impacts of coal-fired power stations underscore the need for transitioning to cleaner and more sustainable energy sources¹⁰.

Solar power: Solar energy generation entails transforming sunlight into electricity, either directly via photovoltaic (PV) cells or indirectly through concentrated solar power (CSP) systems. Photovoltaic cells, commonly known as solar cells, utilize the photovoltaic effect to generate electric current from light. The advantages of solar energy are numerous. It is a renewable energy source, with sunlight projected to be available for at least another 5 billion years according to scientific estimates. Solar power systems can significantly reduce electricity bills, and they generally require low maintenance. Moreover, leading solar panel manufacturers typically provide warranties of 20 to 25 years, guaranteeing sustained performance and reliability over the long term¹¹.

However, there are also several disadvantages associated with solar energy. The upfront investment required for a solar energy system can be substantial, encompassing costs for panels, inverters, batteries, wiring, and installation. Additionally, solar panel efficiency declines under cloudy or rainy conditions, and electricity generation is not possible during nighttime. This intermittency necessitates effective energy storage solutions, which can be costly. Furthermore, solar installations require considerable space, and not all rooftops are suitable or large enough to accommodate the desired number of solar panels. Overall, although solar energy offers a sustainable and promising alternative to fossil fuels, its adoption is limited by substantial upfront costs, fluctuations in energy output, and the space needed for installation. Addressing these challenges is essential for maximizing the potential of solar energy in the global energy mix¹².

Our Technology: Plant-Based Nano Power Plant: Materials Used: i. Living plant in a transparent container, ii. Copper and zinc rods, iii. Connecting wires, iv. LED bulbs, v. Electrodes (cathode and anode), vi. Multimeter.

Mechanism of Bioelectricity Production: Photosynthesis and Respiration: Plants perform photosynthesis to convert sunlight into chemical energy, producing glucose and oxygen. During respiration, glucose is broken down, releasing electrons as part of the plant's natural metabolic processes¹³.

Bioelectricity Generation Process: i. Electrode Placement: Electrodes are inserted into the soil near the plant roots. ii. Electron Harvesting: Soil bacteria decompose organic compounds excreted by the plant roots, releasing free electrons. iii. Electric Current Production: The electrons are captured by the electrodes, generating an electric current that can be utilized to power small devices¹⁴.

Experimental Setup: To validate the concept of bioelectricity generation from living plants, a structured experiment was conducted. The objective was to assess the feasibility of electricity generation using simple, readily available materials and to quantify the voltage and current generated by the system.

Materials and Methods

Two healthy *Epipremnum aureum* (commonly known as money plants) were selected due to their hardiness and continuous root development, which supports stable microbial activity. Each plant was placed in an individual transparent plastic container to allow easy observation of root growth and soil conditions. The growth medium comprised a mixture of fertile garden soil and organic compost to simulate natural conditions and promote microbial activity within the rhizosphere. Electrodes made of copper and zinc were chosen for their differing electrochemical potentials. They were inserted approximately 4–5 cm apart within the soil, near the root zone, to enhance electron transfer efficiency. The zinc electrode served as the anode, whereas the copper electrode functioned as the cathode. These were connected to an external electrical circuit using insulated copper wires¹⁵.

Electrical output was measured using a calibrated digital multimeter configured for low-voltage readings to accurately detect the micro-scale bioelectric signals produced by the system. For load testing, a 3V, 20mA low-power LED was connected across the circuit to evaluate the system's capacity to power an external device. Voltage and current measurements were recorded regularly over a two-week period to evaluate stability, peak performance, and long-term viability. Control experiments were also conducted using identical plant setups without electrodes to validate that the measured electricity originated from the electrochemical setup rather than external environmental factors¹⁶.

For load testing, a low-power LED bulb (rated at 3V, 20mA) was connected across the circuit to visually confirm the system's ability to power external devices. Voltage and current readings were recorded at regular intervals over a two-week period to evaluate the system's electrical stability, peak performance, and long-term viability. Additionally, control measurements were taken from identical plant setups without electrodes to confirm that the observed electricity generation was a result of electrochemical interactions in the root-soil-electrode system, rather than environmental or measurement artifacts¹⁷.

Observations: During the two-week experimental period, the following observations were recorded: i. Voltage output began to stabilize within the first 24–48 hours after electrode insertion, indicating the initiation of consistent electrochemical activity in the rhizosphere. ii. Individual plant systems generated voltages ranging between 1.8 to 2.4 volts, depending on soil moisture and microbial conditions. iii. Peak voltage values reached up to 2.45 volts, with potential capability observed for values approaching 3 volts under optimized conditions. iv. Current output ranged between 20 to 30 microamperes, which is typical for small-scale plant microbial fuel cell (PMFC) setups. v. The connected LED (3V, 20mA) displayed intermittent but noticeable illumination, particularly when soil moisture was optimal or when multiple plant units were connected in series. vi. Voltage generation was positively correlated with root activity and microbial presence, reaffirming the role of biological processes in bioelectric output^{18,19}.

Advantages: i. Eco-Friendly: This method of electricity generation has a minimal environmental impact, reducing the carbon footprint compared to traditional power sources. It harnesses natural processes without emitting harmful pollutants or greenhouse gases, contributing to cleaner air and a healthier planet. ii. Ecological: The system promotes biodiversity and supports healthy ecosystems by utilizing living plants in their natural environment. Unlike industrial energy systems, this approach does not require habitat destruction or significant alterations to the landscape²⁰. iii. Natural Process: The technology leverages the natural metabolic processes of plants and soil bacteria, making it a sustainable and renewable energy solution. This use of biological systems for energy production ensures that the process is harmonious with nature. iv. Green Technology: As a form of green technology, this approach aligns with the principles of sustainability and environmental stewardship. It provides a clean alternative to fossil fuels, supporting global efforts to transition to renewable energy sources²¹. v. Free Electricity Generation: Once the system is set up, it can generate electricity continuously without ongoing fuel costs. Dependence on abundant natural resources, including sunlight and soil nutrients, ensures that it remains a cost-effective solution over the long term. vi. No Waste: The process does not produce hazardous waste products, such as radioactive materials or chemical pollutants, which are common in other forms of energy production.

This lack of waste production reduces the environmental burden and simplifies waste management. vii. No Effect on Plant Growth: The method is non-invasive and does not hinder the growth or health of the plants involved. By allowing plants to continue their natural life processes unhindered, the system maintains the integrity of the ecosystem while providing a steady supply of electricity^{22, 23}.

Results and Discussion

The experimental arrangement successfully illustrated the potential for producing sustainable bioelectricity from living plants through a plant microbial fuel cell system. The system produced sufficient voltage to intermittently power low-power electronic devices, such as LEDs. Key findings include: i. Peak voltage achieved: Up to 2.45 volts per plant system under observed conditions, ii. Maximum potential: Voltage output exhibited capacity to reach up to 3 volts with optimized conditions and system enhancements, iii. Average voltage output: 1.8 – 2.3 volts, iv. Average current output: 20 – 30 microamperes, v. Output stability: Sustained voltage generation over a continuous 14-day observation period, vi. Successful LED illumination: A 3V LED was intermittently illuminated using a single plant system; combining two or more systems in series enhanced illumination consistency and brightness.

These findings confirm the core concept that electrons generated by soil microbes during organic matter decomposition can be efficiently captured using inert electrodes positioned close to plant roots. The experiment provides a proof-of-concept for further development and scaling of this technology^{24,25}.



Figure-2: Experimental setup of a plant-based nano power plant using *Epipremnum aureum* to generate electricity via root-zone microbial activity.

Table-1: Previous Work Summary.

Reference	Year	Study Focus	Key Findings
17	2017	Bioelectricity from living plants	Introduced plant-based electricity generation system
18	2008	Green electricity with plant bacteria	Verified stable bioelectricity generation in PMFCs
15	2016	Plant bioelectricity modeling	Modeled electricity generation from living plants
19	2023	Plant-MFC performance	Demonstrated bioelectricity potential using microbial fuel cells

Conclusion

The increasing urgency to mitigate climate change underscores the critical need for developing renewable and environmentally sustainable energy technologies. This study demonstrates the viability of a plant-based nano power plant that leverages microbial activity in the rhizosphere of *Epipremnum aureum* to generate low-power bioelectricity. The system, using simple copper and zinc electrodes, successfully produced stable voltage outputs with peaks up to 2.45 V and potential reaching 3 V sufficient to intermittently power small devices such as LEDs.

By harnessing naturally occurring biological processes without harming plant health, this technology presents a clean, low-cost, and scalable alternative to conventional fossil fuel-based energy systems. In addition to its energy benefits, it contributes to ecological sustainability by promoting biodiversity, soil health, and minimal environmental impact. The findings support the potential for further development and integration of plant microbial fuel cells (PMFCs) in decentralized or off-grid power applications.

Future Work: Future research will focus on scaling the technology for higher power outputs and integrating plant-based electricity generation into smart agriculture and urban green infrastructure, such as green roofs and living walls. Large-scale studies and long-term monitoring will be essential to optimize system efficiency and assess the broader ecological benefits.

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