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Investigative Study on Potential Electrical Signals from Palm Trees in Gaza Strip

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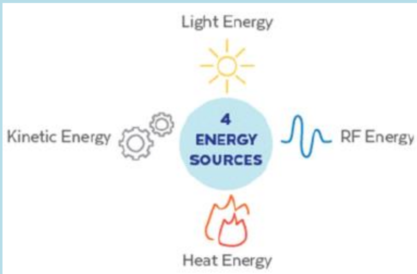
Abstract: This paper aims to analyze the electrical signals in a group of palm trees in the regions of Gaza City and Deir Albalah. It also investigates the stimuli of electrical potential (EP) in dates palm trees. It also explains factors such as: light, temperature, water level, tree age, sunset, direction, changing the reference, distance and proximity to the reference and electrode placement as stimuli on the EP of date palm trees. It assesses electrical signals (ESs) types in dates palm trees, generation and propagation of several ESs such action potential (AP), virtual potential (VP). The paper also demonstrates energy harvest potential, perspective applications and practical applications. The paper also provides a review summary of the effects of ESs on tipping, pruning, sunset, daybreak, photosynthesis, of lighting conditions, water availability.



Keywords: Energy Harvesting, Trees Electrical Signals, Renewable Energy Sources.

INTRODUCTION

The digital age, industry 4.0 and Internet of Things (IoT), is expected to reach over 10 billion by 2025 and needs sustainable energy to power these devices [1]. Currently, IoT devices includes portable radios, environmental sensors, calculators, personal electronic devices, health monitoring devices, smartphones, power tools, TVs, laptops, digital cameras, and many more are powered by primary and secondary batteries. Replacing and discarding billions of batteries will require enormous efforts and labour.

Renewable energy is an environmentally-friendly source. The concept of energy harvesting refers to capturing, accumulating and storing small amounts of energy, then converting it into power electricity [2]. The harvested energy can either stored for later use or can be used for immediate devices or in applications. Energy harvesting and battery-less solutions to the IoT are new research fields. Energy may be harvested from four different sources: heat, light, kinetic, and RF as shown in Figure 1 [2].

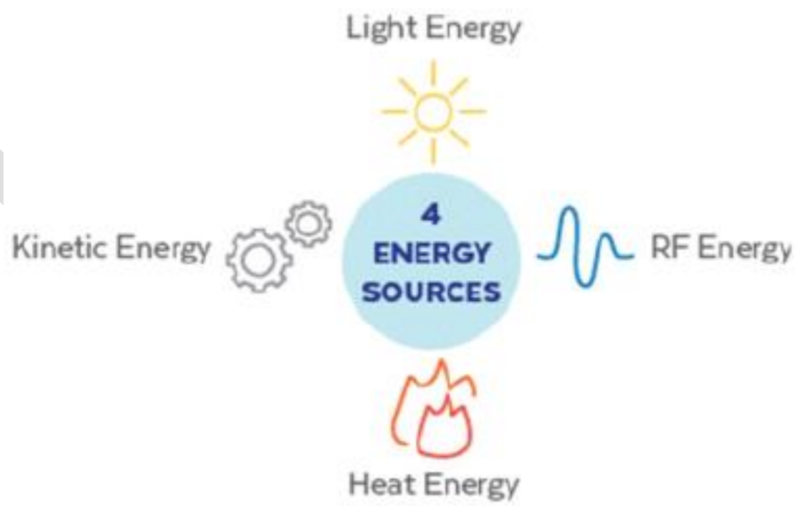


Figure (1): Sources of harvested energy.

The basic energy harvesting system consists of four components: the harvester, the energy storage, the power management, and the electric load as shown in Figure 2. The energy harvesters use typical transducers such as: Photovoltaic with light, Thermoelectric with heat, RF with radio frequency and Piezoelectric with kinetic. The energy storage can be a battery or heat storing

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devices while the power management may include conditioners for electrical energy such as electronic control circuits and power regulators [2].

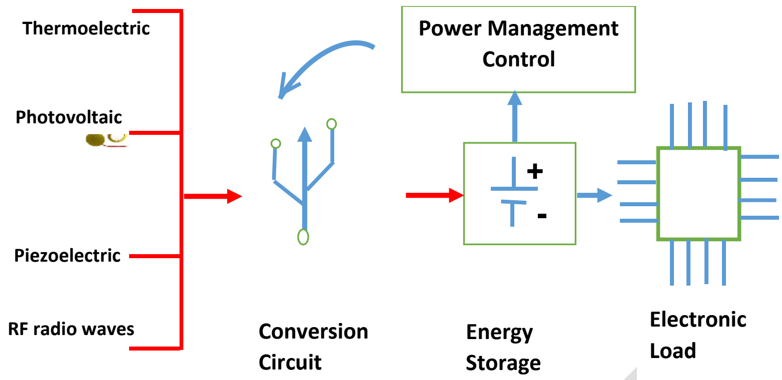

Figure (2): Basic components of harvesting system.

Wireless Sensor Nodes, WSN, depends on low energy power batteries. One problem facing Wireless Sensor Nodes, WSN, is that they run out of power [3]. To extend the lifetime of WSN, a natural environmental autonomous energy source can be used [4]. This requires energy harvesting from the surrounding environment.

Over the last few decades, the world has faced a steady increase in demands on energy due to economic and population growth [5]. Increased in energy prices acts as a barrier to economic growth [6]. Traditional fossil fuel energy sources are unsustainable and cause harm to the environment [6]-[8]. The rise in demands for renewable energy (RE) has increased significantly over the last few years because of the appeal towards green and sustainable energy sources [8]-[10]. Advances in solar and wind energy technology and the drop in their cost made them the most utilized form of renewable energy [9],[10].

Electrical potential inside plants and trees has gained more attention in the research community lately due to their organic mechanism, the ability to reduce Carbon Dioxide and to maintain the surrounding temperature [11]. Trees display electrical activity where there exists a continuous electrical potential difference between electrodes inserted in the tree's trunk and its contiguous soil [12],[13]. Thus, there is a need to study the excitable of plants and trees membranes through electrical excitations [14] and to configure it as a potential sustainable renewable energy source.

The biological structure in living plants can be utilized for electrochemical conduction [14] and excitation to broadcast signals. A fluctuation of electrical signals can be formed when electrodes are inserted into trees which results in potentials that eventually stabilizes at rest. The resulted reaction will allow small changes in membrane becoming conductive or allow ionization along channels of electrical current [10], [13], [17].

Koppán et. al. [18] detected and recorded the electric potential difference for two years by inserting a non-polarizing electrode. The recorded signal varied between 15-50 mV daily during vegetation period. Another study found that resistance is lower during plant watering [19].

Based on previous studies, there is clear evidence that harvesting energy from living plants is possible. Therefore, this research investigates the potential energy that can be harvested from local living trees in Gaza Strip. Date palm trees may be found in homes, streets, universities, and institutions. This research investigates the potential of electrical energy in dates palm trees. Multiple random experiments were conducted and recorded on different trees at the Islamic University of Gaza and Deir Albalah for a yearlong. The research provides data and information on harvesting energy from date palm trees. The research recommends the best conditions for maximum energy harvesting and provides a model for best way to harvest energy from palm trees.

This paper is organized as follows: Section 2 outlines the energy harvesting methods, Section 3 presents the results, challenges and future perspective on the harvesting energy from living plant and trees, Section 5 concludes this study.

II. Energy Harvesting Methods

Renewable energies have emerged as an alternative cost-efficient power generation [20]-[25]. Wind, hydropower, solar, geothermal and biomass provide sustainable energy sources that are utilized globally. New technology was utilized such sources on low-powered portable devices. Micro-renewable energy research [26], refer to harvesting very small amount of energy, such as piezoelectric, thermoelectric, and resonant frequency (RF). Specific technology and concept can be utilized to extract energy from plants and trees. The potential of energy extraction is based on Motion and Vibrations [26]-[28].

The electrical voltage measured in the trees is based on the concept of pH imbalance produced between the tree and its surrounding soil. Absorbed water, nutrients and charged particles flow in the xylem produce an electric current circulating between parts of the trees [26].

Factors influencing electrical potential: Recent research found that electrical signals can be produced due to plants interaction with their environment [16]. EP may be influenced by environmental factors such as: water, humidity, soil, fertility, humidity light, and air temperature. There are two types of electrical signals, variation potential and action potential. Plants are affected by external stimuli and as a result they produce EP may be AP or VP, but they are weak so they need to be amplified [26]. There are many factors that affect EP. In tipping and pruning when the distance relatives to the electrode increased, the EP decreased [24]. EP values decreased after dawn, but began to increase after midday due to transient water stress conditions [27]-[29].

EP increases under sunlight [30], atmospheric evaporative demand (AED) [30], soil wetting increases. Young trees have higher voltage measurements than older trees [30]. Directions have an impact on the measurements and differ from one direction to another [30]. The highest values were noticed during fall and spring seasons [26]. In contrast, minimum values were recorded during summer and winter seasons due to lack of growth activity. However, studies showed that no correlation exists between the atmospheric pressure and measured voltages [28].

Increasing the number of electrode pairs, thus increasing the available signals, then adding external conditioning circuit that act to stabilize the power output can improve the voltage output obtained from the tree. Calculators and digital clock and other low power applications can act as natural case studies [27].

Energy from Electrode Potential: Using different metals as electrode potential [31] is based on electrochemical cell concept that can produce electric current flow. Zinc and copper metals can be used as electrodes and soil and tree trucks can act as electrolytes [31]. Zinc tends to lose electrons through an external conductor connection. Oxidation is a process that takes place at the anode side while at the cathode side, zinc, loses its mass. A chemical reaction occurs between zinc and copper that are separated by an electrolyte. Zinc will dissolve into the electrolyte and releases its electrons and copper will gain mass from its electrolyte by absorbing those electrons. Equation (1) shows this chemical reaction

$$Zn + Cu^2 + SO_2^{4-} \rightarrow Zn^2 + SO_2^{4-} + Cu \quad (1)$$

To excite zinc's electrons and cause the movement of electrons from zinc to copper an external energy in needed to be absorbed, thus, generating electromotive force (emf).

During photosynthesis a plant produces organic matter that results in plant-growth; however, a large portion of it goes unused and is excreted through the roots into the soil. In the area surrounding the roots, the organic compounds are broken; thus, releasing electrons as a waste product. By inserting an electrode in that area, the electrons can be harvested as electricity [32].

Used electrolytes for the soil and the tree trucks have different contents. While the tree electrolytes are formed from water and nutrition that flow from the roots to the leaves through the trunks, water and minerals in the soil form soil electrolytes. The electrolytes and the electrodes act as fuel cell system and generates energy [33]. The efficiency of the fuel cells varies according to used materials [34]; so is electrode potential varies based on different used metals. Thus, the type of used electrode metal plays a significant role in tree energy harvesting. Selecting the appropriate metal will improve the energy harvesting. Table 1 shows electrode potential for certain metals.

Table (1): Electrode potential of certain metals [34].

Metal	Potential (Volts)	Metal	Potential (Volts)
Aluminium	+1.30	Arsenic	-0.32
Zinc	+0.758	Copper	-0.345
Iron	+0.441	Silver	-0.80
Nickel	+0.22	Gold	-1.10

A. Living Plant Bio-Energy Fuel Cell

Trees have shown to own electrical properties [30] making them a prime energy harvesting source. Cainan et. al. [35] measured electricity of 0.8V – 1.2V by inserting half an inch of aluminum roofing nail to tree and copper water pipe seven inches into the ground [36]. "Streaming potential" mechanism [37] was the main reason behind this difference and this potential was utilized in monitoring plant activity. The bioelectricity in the xylem depends on air relative humidity, soil temperature and material of electrode [34] where lower temperature reduces bioelectricity, while higher moisture and sunlight increase the power output [38], [39]. Significant energy can be harnessed and utilized by low-power electronics using suitable electrode material and trees with compatible electrochemical properties. A comprehensive understanding of the research methodology is crucial for accurately interpreting the voltage and current readings generated by palm date trees. This section elaborates on the experimental setup and the various factors that can influence the electrical outputs, ensuring a thorough analysis of the results.

Factors Affecting Voltage and Current Readings: Environmental Conditions such as soil moisture, temperature, and light intensity. Higher soil moisture generally leads to better conductivity and potentially higher current readings. Temperature variations can impact the metabolic activities within the tree and the conductivity of the electrodes, leading to fluctuations in voltage and current. Photosynthetic activity, driven by light intensity, can affect the bio-electrochemical processes within the tree, thereby influencing the electrical outputs. Tree Health and Physiology such as sap flow, nutrient levels and growth stage. The movement of sap within the tree can carry ions that contribute to the electrical signals. Variations in sap flow due to tree health or seasonal changes can affect the readings. The availability of nutrients can impact the metabolic processes within the tree, influencing the generation of bioelectricity. Different growth stages of the tree (e.g., young vs. mature) may exhibit varying electrical characteristics due to differences in metabolic activity and structural properties. Electrode Characteristics such as material, corrosion, and contact resistance. The type of material used for the electrodes can affect the contact resistance and the efficiency of signal capture. Over time, electrodes can corrode, especially in moist environments, which can alter the conductivity and affect the readings. Poor contact can lead to higher resistance and lower current readings. Measurement Configuration such as circuit design, calibration, and data acquisition rate. The design of the measurement circuit, including the placement of resistors and the configuration of the electrodes, can impact the readings. Any drift in the calibration can lead to erroneous data. The frequency at which data is recorded can influence the ability to capture transient phenomena and provide a comprehensive understanding of the electrical signals. Data Analysis and Interpretation: Baseline measurements under controlled conditions (e.g., stable temperature and soil moisture) are essential for comparison with experimental data. Techniques such as signal filtering and averaging can help reduce noise and improve the accuracy of the readings. Comparing the electrical outputs from palm date trees with those from established energy sources (e.g., PV systems) can provide a context for evaluating the feasibility and potential applications of this unconventional source.

B. *Experiments Setting*

Electrode insertion utilizes electrodes that are typically made of conductive materials like copper or stainless steel to ensure efficient electrical conduction. Electrodes are inserted into the tree at specific points, such as the trunk and roots, to capture the bioelectrical signals. The depth and ***positioning*** of the electrodes can significantly affect the readings. Electrodes are connected to a sensitive ammeter or data acquisition system capable of measuring low currents and voltages. The experiments were conducted outside of laboratories under the natural situations of eleven date palm trees located in Gaza Strip, Palestine (6 at the Islamic University of Gaza – Gaza Campus, the other five in Deir Albalah at two nearby sites). The measurements were taken over 9 months periods during daytime and night-time. Two types of electrodes, locally abundant and easily available, were used: iron and steel. The electrodes (screws with diameters of 2 mm and a length of 6 cm) inserted into the tree's trunks in order to make contact with the inner tree tissues and without causing a serious injury for trees. The electrodes inserted in the soil were iron (rods with diameters of 10 mm, and length of 70 cm). The height at which the screws were inserted varied between 90 cm-150 cm. the radius at which the iron rods were placed away from the trunk of the trees ranged between 2m-3m.

Date palm cultivation has been known in Palestine for thousands of years. They have attracted the attention of Palestinian farmer for being a source of pride and have an enormous economic value in addition to spiritual inspiration. They live for hundreds of years, and have the ability to resist harsh climatic conditions, moreover, they can grow in saline soils. Palm cultivation in Palestine is widespread in all regions. The city of Jericho in the Jordan Valley and the city of Deir Albalah in the Gaza Strip are historically called the "City of Palms"; because of the large number of date palm planted within their city limits [32].

The selected trees (date palm-Deir Albalah tree) are available in abundance locally and size of trunk easily allow for electrode insertion. The age of the date palm trees is between 15-17 years old. The trees were in good health and displayed normal growth and trunk size. All the trees were located at three different sites (Islamic University of Gaza- main campus, Deir Albalah – Albasa neighbourhood) with similar orientation, and water availability Figure 3 shows a sample of these trees.

The trunk electrodes were screwed in direct contact with the tree's phloem tissue for about 5 cm. The position of the trunk electrodes was at height of 90-150 cm above ground facing east. The ground electrodes rods were placed 30 cm into the ground at a radius of 2-3 m away from the trunk of the tree.

The open-circuit voltage and short-circuit current were measured using an off-the shelf type of multi-meter, UT33D UNI-T as shown in Figure 4.a. It characteristics include: input impedance of 10 MΩ, accuracy of ± (0.5% + 2 digits) millivolts (mV) and ±(1% + 2 digits) microampere (μA), and a resolution of 0.1mV (DC) and 1 μA (DC). 1 mm copper cables insulated with a flexible plastic coating were used for connecting the electrodes with the multi-meter. Figure 4 shows used tools.

Measurement Devices: A high-precision ammeter with the capability to detect microampere (μA) to milliampere (mA) currents is used. A voltmeter with a high input impedance is employed to measure the voltage without significantly altering the circuit. A data logger may be used to continuously record the electrical signals over time, providing insights into temporal variations.

Figure (3): Sample of the date palm trees.

a) Multi-meter

b) meter

c) wires

d) screws e) screw drivers f) iron rod

Figure (4): Experiment tools.

The screws were used as tree electrodes because they can be easily inserted and removed from trees without causing much damage to tree itself. At worst, they can cause minimum injury. The electrodes were placed in a manner of circular and longitudinal distribution based on predetermined the distribution of potential difference along each diameter of the tree. The poles were placed in a circular shape, at a height of 140 cm and a diameter of 114 cm, in the four directions, north-east, west-south. The electrodes were placed on the faces of the trees as shown in Figure (5).

Screws were inserted directly into the trunk making contact with the phloem tissue. The cortex plays an active role in the electrical response. The next section presents, analyzes and discusses the obtained results.

III. The results

The results were obtained during the year 2022. The following tables represents samples of the measurements of the open-circuit voltages. The measured short-circuit currents ranged from 35 – 53 micro amperes. The measurements were obtained over various seasons and over daytime and night-time. The measurements showed that measured voltages and currents were higher during night time. During irrigation time measurements were similar to other times. However, when soil was dry, measurements were lower.

A. V1 (at the east direction) is reference

The voltages V1, V2, V3, V4 are taken at the same height but in a different direction. while voltages V4, V5, V6 are taken at different heights but in the same direction (north) as shown in the Figure (5).

Table (2): V1 is REF [Date: 6/12/2022 at 9:30am.

Voltage number	Voltage (v)	Distance (cm)
V1-V2	0.06	25
V1-V3	0.04	52
V1-V4	0.31	87
V1-V5	0.16	30
V1-V6	0.32	38

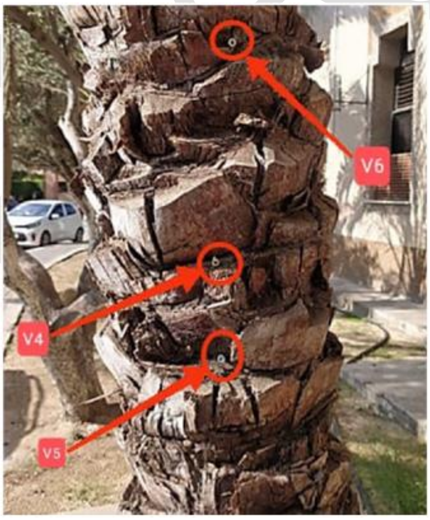

Figure (5): The electrode placement in the tree.

As for the polarity, the distance between the reference point and each point does not have a fixed relationship in its effect on the voltage. The highest recorded voltage value was at V4 located north of the reference and the lowest value was at V3 located west of the reference as shown in Table (2).

B. Ground is reference

The distance between tree and ground is 300 cm.

As for the height, there is no fixed relationship between the voltage and the height. The highest recorded voltage value was at V4 and the lowest was at V6, even though they are in the same direction. As for the polarity, the results of the voltage difference were very similar at V1, V2 and V3 located east, south and west, respectively, while the value at V4 located north was much greater than the other values as shown in Table 3.

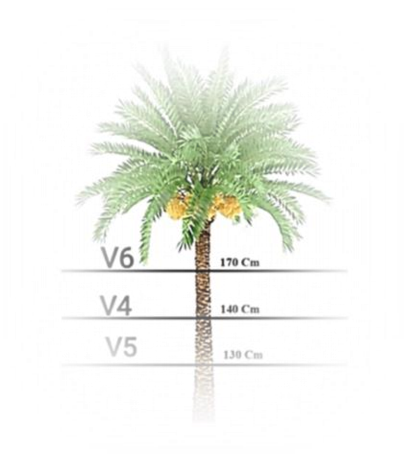

Figure (6): The voltage of V4, V5, V6

Table (3): Ground is REF [Date: 6/12/2022 at 10:20 am].

Voltage number	Voltage (v)	Diameter (cm)	Height (cm)
V1	0.54	114	146
V2	0.56	114	146
V3	0.55	114	146
V4	0.69	114	146
V5	0.24	108	135
V6	0.20	110	170

C. Tree #2 is REF

Distance between tree 1 and tree 2 is 590 cm. As for the height, there is no fixed relationship between the voltage and the height when the reference is the second tree. The highest recorded voltage value was at V6 and the lowest was at V4. As for the polarity, the highest value of the potential difference was at V4 in the north, then V2 in the south, but at V3, and V1 in the west and east, respectively, the voltage value did not exist as shown in Table 4.

Table (4): Tree #2 is REF [Date: 6/12/2022 at 10:40 am].

VOLTAGE NUMBER	VOLTAGE (v)
V1	0
V2	0.02
V3	0
V4	0.14
V5	0.27
V6	0.32

D. Comparison based on age

The first tree (T1) is an old tree, and the second tree (T2) is middle-aged. The readings were taken at the same heights in the two trees and in the same direction (north). Measurements were taken in September 2022. The voltage values in the middle-aged tree were always greater than the voltage values in the old tree. The effect of age difference on voltage value is shown in Table 5.

E. Comparison by seasons

The results obtained during the winter were greater than the results in the summer due to several factors, including: increased water content in the soil, soil moisture, sun, heat radiation, air temperature and speed. While in the harvest season (autumn), the voltage difference values were zero, due to the decrease in the movement of food and water transport in the

Table (5): Voltage of tree #2 and voltage of tree #1

VOLTAGE OF TREE #1	VOLTAGE OF TREE #2
0.26	0.31
0.2	0.33
0.23	0.43
0.18	0.37
0.27	0.44

tree's containers, which were moving to feed the rest of the tree's parts as shown in Table 6. Distance between tree and ground is 300 cm.

Table (6): GND is REF [Dates: July 10, Oct 24, Dec 10, 22].

Voltage number	Voltage Winter (mV)	Voltage Summer (mV)	Voltage Fall (mV)
V1	0.24	0.15	0
V2	0.69	0.26	0
V3	0.20	0.44	0

F. Comparison based on soil moisture (irrigation)

The palm trees were watered until their soil became moist, then measurements were taken with V4 as a reference and ground as a reference.

V4 is reference: The northern voltage (V4) was chosen as a reference because it is in the longitudinal and polar measurement mode. The measurements show: As for the height, the distance has effect on the voltage readings, the greatest value of the voltage was at V6 and the least value of the voltage at V5 as shown in Table 7. As for the polarity, the greatest value of the voltage was at V1 in the eastern direction and the least value of the voltage V3 was in the western direction.

Table (7): V4 is REF [Date: 25/1/2023 at 12:35 am].

Voltage number	V4-REF Voltage (v)	GND-REF Voltage (v)
V1	0.32	0.01
V2	0.04	0.35
V3	0	0.32
V4	0	0.02
V5	0.02	0.01
V6	0.28	0

Ground is REF: As for the height, the distance has effect on the voltage readings, the greatest value of the voltage was at V2 in the southern direction, and the least value of the voltage was at V6 in the northern direction, as shown in Table 7. As for the polarity, the greatest value of the voltage was at V2 in the southern direction, and the least value of the voltage was at V1 in the Eastern direction, as shown in Table 7.

G. Current measurements

For palm date trees specifically, currents measured are in the range of a few microamperes (1-10 µA). These precise measurements depend on factors like tree health, environmental conditions (such as soil moisture, temperature), and the specific bio-electrochemical mechanisms involved. The data is in line with a study titled "Bioelectricity: A Sustainable Energy Source from Plants" by researchers at Wageningen University explored the potential of generating electricity from living plants. They found that the currents generated were very low, often in the range of a few microamperes (µA) to milliamperes (mA). The feasibility of generating meaningful amounts of electricity from palm date trees hinges on several critical factors, including the magnitude of the generated current and voltage, the consistency of these outputs, and the overall efficiency compared to established energy systems like photovoltaic (PV) systems. Typical Measurements: Voltage approximately ranges between 0.2 to 1.0 volts and current ranges from a few microamperes to tens of microamperes under standard conditions.

H. Comparisons to other renewables

While the concept of generating electricity from palm date trees is intriguing, the feasibility is constrained by the low current outputs compared to established energy systems like PV systems. For practical energy generation, PV systems remain far superior in terms of efficiency, scalability, and reliability. However, continued research into bioelectricity may uncover specific applications where this technology can be effectively utilized. While the exploration of unconventional energy sources like bioelectricity from palm date trees is commendable, it is essential to weigh their potential benefits against the extensive research, optimization, and implementation of established energy sources. Solar PV, wind, hydroelectric, and bioenergy systems have proven their efficacy and continue to evolve, offering reliable and scalable solutions to the global energy demand. Unconventional sources may find their niche in specific applications, but their broader adoption will depend on overcoming significant technical and practical challenges. Bioelectricity from trees could provide a sustainable and low-impact energy source, it fosters innovation and can lead to breakthroughs that complement existing technologies; however, it offers lower energy densities compared to established methods, limiting their scalability and practical applications, can be inconsistent, influenced by environmental factors and biological processes and requires significant time and resources.

I. Practical applications for palm trees electricity

While the electricity generated from palm trees may be limited in scale, it can find valuable applications in specific niches where low power is sufficient, and sustainability is a priority. Environmental monitoring systems, remote weather stations, low-energy LED lighting, small-scale electronic devices, educational tools, and health monitoring devices are all practical examples where bioelectricity can make a meaningful impact. By leveraging the unique characteristics of bioelectricity, these applications can enhance sustainability, improve resource efficiency, and provide valuable services in remote or resource-limited settings

CONCLUSION

This research focused on palm trees as a source of energy. The objectives of the research are to investigate the potential energy that can be harvested from palm trees and to investigate the conditions that can improve and give energy harvesting. Steele screws (7 cm) were inserted in palm trees and iron pole (70 cm) in the ground. The voltage was directly measured in palm trees of different ages with wires. The results showed that electrical energy existed in those trees. The voltage values were affected by many factors such as: the reference point where the voltage value increases with increasing distance between tree trunk and ground reference, polarity when facing east showed better values, tree age where younger trees possessed greater voltage values, sunlight where there were more activities during daytime, season where winter recorded the highest. The potential for future applications includes monitoring plant health/fire using electricity harnessed from trees to power sensing electronics to measure surrounding heat and humidity. Network coverage and reporting system can be implemented using trees harnessed energy to power wireless communication networks; thus, expanding the coverage to remote areas. IOT systems can be powered by energy harvested from trees. Challenge in living plants and trees energy harvesting faced the problem of keeping the plant healthy and the electrode undamaged. Failing is the main challenge for long-term operation of plant energy.

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