edunet foundation

Biophotovoltaic System

Executive Summary

The BioVoltaic Energy System is an innovative solution that generates electricity using fruit juice electrolytes instead of traditional silicon solar cells. This concept aims to provide a low-cost, eco-friendly, and accessible energy alternative, especially for rural communities and regions with limited access to traditional renewable technologies. The system is implemented using simple web technologies (HTML, CSS, JavaScript), focusing on demonstrating the feasibility and future potential of fruit-based electricity generation.
This report outlines the problem, solution, market potential, challenges, and long-term business viability of the project.

Problem Statement

- Rural areas and small farmers still face electricity shortages and high energy costs.
- Traditional solar panels are expensive, require high sunlight, and are not suitable for all regions.
- Fruits and fruit waste that farmers cannot sell go unused and become agricultural waste.
- There is no affordable portable energy solution for rural households, small shops, and emergency situations.
- Need for a low-cost, biodegradable, eco-friendly alternative energy source.

Project Overview

The BioVoltaic Energy System is an innovative electricity-generation model that uses fruit juice electrolytes instead of silicon solar cells.
This project demonstrates how natural fruit acids and electrolytes can be used to produce voltage through an organic electrochemical reaction.
The system includes:

- A web-based UI built using HTML, CSS, and JavaScript
- A fruit selection dashboard
- Display of voltage output, acidity, pH level, and cost calculation
- Concept demonstration for portable bio-solar panels

This version focuses on concept implementation, while Machine Learning and Deep Learning are planned for future enhancements.

Objective

- Demonstrate fruit-based electricity generation.
- Build a clean and intuitive web-based simulation.
- Educate users about eco-friendly energy alternatives.
- provide a foundation for future scientific and tech-based enhancements.
- Encourage adoption of organic and biodegradable energy solutions.

Solution Offered

- A low-cost, portable **fruit-juice-based solar electricity model**.
- Converts natural fruit acids into usable voltage using eco-friendly electrodes.
- Provides a digital dashboard to calculate:
  - ✓ Expected voltage
  - ✓ Cost of fruit
  - ✓ Operational efficiency
  - ✓ Best fruit options
- Helps farmers **reuse unsold or low-grade fruits** to generate electricity.
- Offers an eco-friendly renewable energy source without carbon footprint.
- Electrochemical reaction:-
- **At the Copper Electrode (Cathode – reduction):**

  $$2H^+ + 2e^- \rightarrow H_2$$

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Who Are The End Users?

- Farmers – to utilize unsold fruits and generate small-scale electricity.
- Rural households – for powering LEDs, small devices, and emergency lights.
- Schools & Colleges – for science experiments and renewable energy labs.
- Disaster relief camps – portable power when electricity is unavailable.
- Environmental NGOs – promoting sustainable green energy.
- Innovators & startups exploring organic solar technology.

Technology Used To Solve The Problem

- 1. Frontend Technologies (User Interface Layer)
- HTML5
  Used to build the structural layout of the application. It allows clear presentation of fruit properties, voltage calculations, and user inputs in a clean and organized format.
- CSS3
  Applied for designing an attractive, modern, and user-friendly interface. The styling ensures smooth user experience, clarity of information, and appealing visualization for demonstrations and business presentations.
- JavaScript
  Enables the interactive features of the system, such as dynamic calculations, fruit data display, and operational simulation. JavaScript handles:
  - Voltage estimation logic
  - Display updates
  - User input handling
  - Basic decision rules (NOT ML)

2. Hardware Concept Technologies
Copper and Zinc Electrodes
These electrodes react with the natural acids in fruits to produce voltage through an electrochemical process.
Fruit Juice Electrolytes
Fruits act as natural energy sources due to their acidic properties (pH, citrate content, etc.). This concept demonstrates how bio-matter can replace traditional silicon-based solar cells.

3. Development Tools Used
VS Code for writing and organizing the project files
Git & GitHub for version control and project management
Vite (optional) for faster development and cleaner project structure

Challenges Faced

1. No Available Dataset:- There is no ready-made dataset for fruit-based electricity generation.
Important values like voltage output, acidity, and conductivity are not documented anywhere, which made data-driven analysis impossible.
2. Natural Variability of Fruits:- Fruits differ in ripeness, size, and chemical content.
Because of this, even the same fruit type gives different voltage readings, making it difficult to create consistent or reliable data.
3. Limited Resources & Tools:- The project was developed using only HTML, CSS, and JavaScript.
Without laboratory equipment or sensors, real measurements could not be taken, so the system had to focus on simulation rather than physical testing.
4. Time Constraints:- Creating a scientific dataset for many fruits would take weeks of controlled experiments.
Due to limited time, the project focused on building the concept and user interface instead of collecting large-scale data.
5. No Standard Measurement Guidelines ; There is no standard method for measuring fruit electricity, which makes comparisons and accurate recording difficult.

Limitations

- The system is concept-based and not connected to real hardware.
- No real-time voltage measurement is included.
- Fruit electricity can power only small devices, not heavy loads.
- No backend or database is integrated in this version.
- No Machine Learning or predictive analysis is used.
- Fruit properties shown are static, not dynamically updated.
- Fruits decay quickly, reducing energy output over time.
- Lack of standardized measurement methods affects accuracy.
- Environmental factors like season and freshness are not simulated.

SWOT Analysis

Strengths

- Sustainable and eco-friendly
- Low production cost
- Educational value
- Simple and safe technology

Weaknesses

- Low power output
- Fruit decay reduces performance
- Not yet market-ready for large-scale use

Opportunities

- Government renewable energy initiatives
- Partnership with agricultural bodies
- STEM kits for schools and colleges
- Innovation grants & funding

Threats

- Competition from traditional solar panels
- Seasonal variation in fruit availability
- Limited awareness about BioVoltaic technology

Future Scope

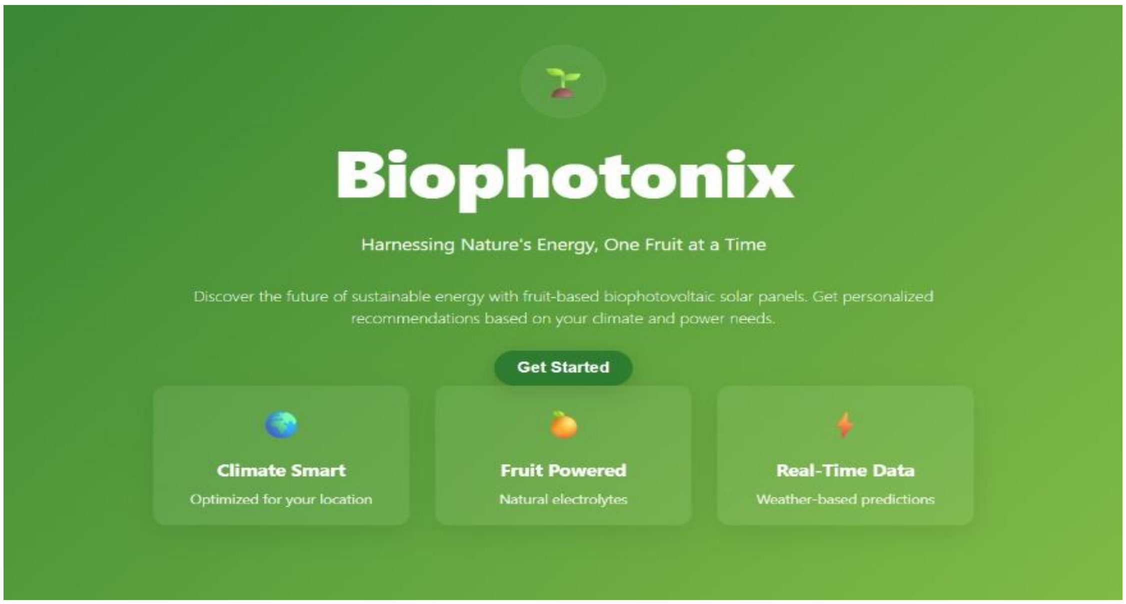
- Integration of sensors for real-time voltage monitoring.
- Building a small hardware prototype with actual electrodes.
- Adding ML model for predicting best fruit based on weather and acidity (future).
- Developing a portable BioVoltaic power bank.
- Creating a dataset through controlled laboratory testing.
- 3D UI visualization and mobile app version.

Conclusion

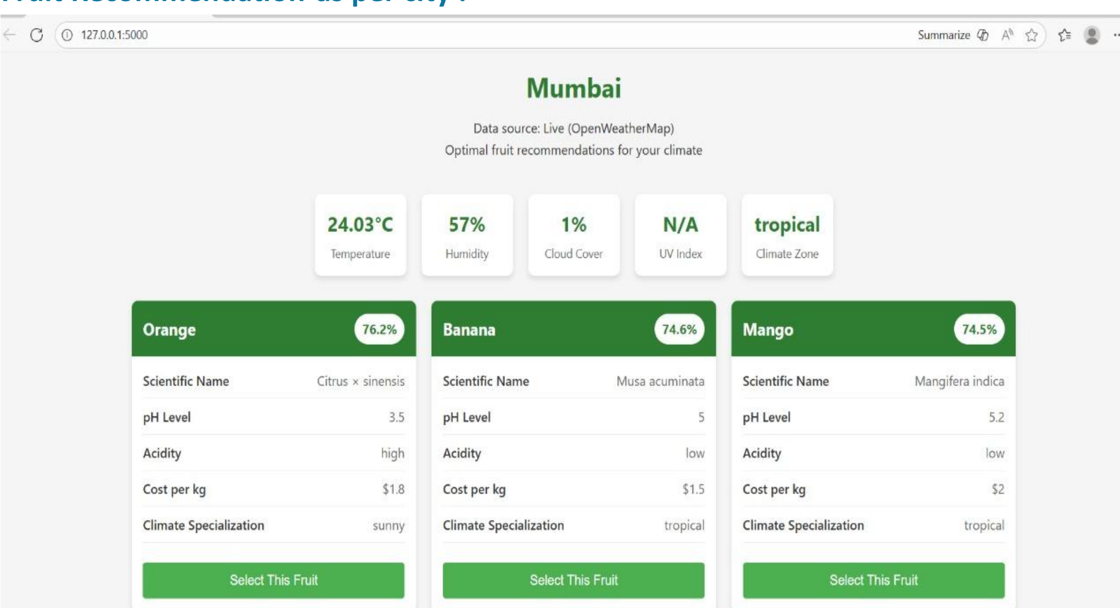
The BioVoltaic Energy System presents a unique and sustainable approach to micro-level electricity generation using organic materials. While the current version focuses on conceptual demonstration through a web-based interface, it lays the foundation for future scientific research, product development, and commercial opportunities. With advancements in data collection, hardware integration, and renewable energy innovation, this project has the potential to evolve into a cost-effective eco-energy solution for rural and educational applications.

Annexure – A: Output Screenshots

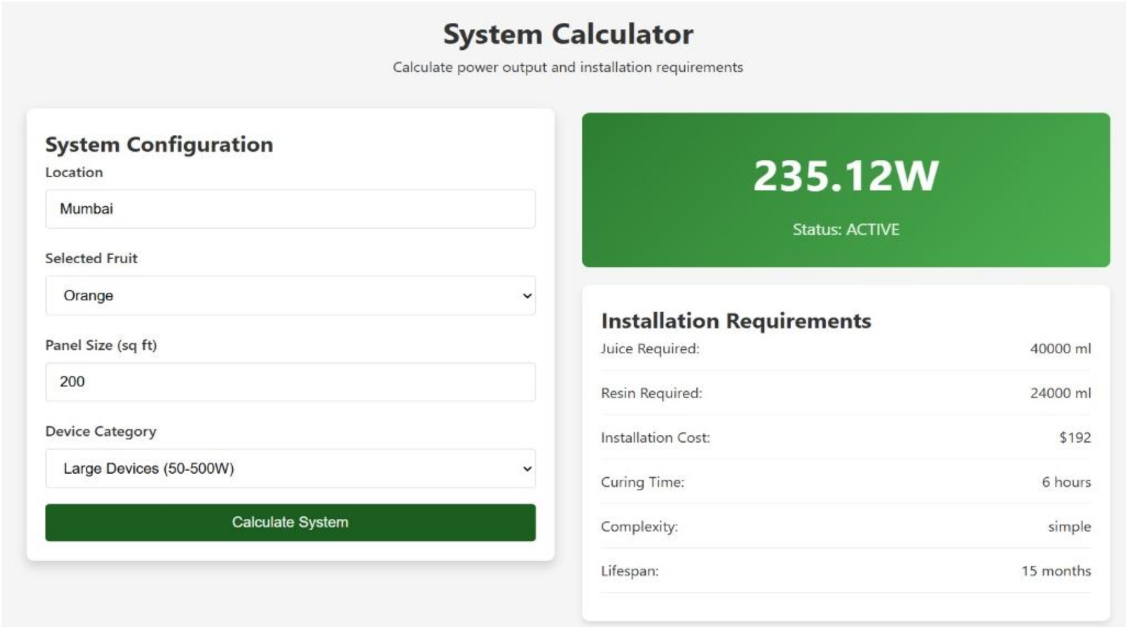
Homepage:-



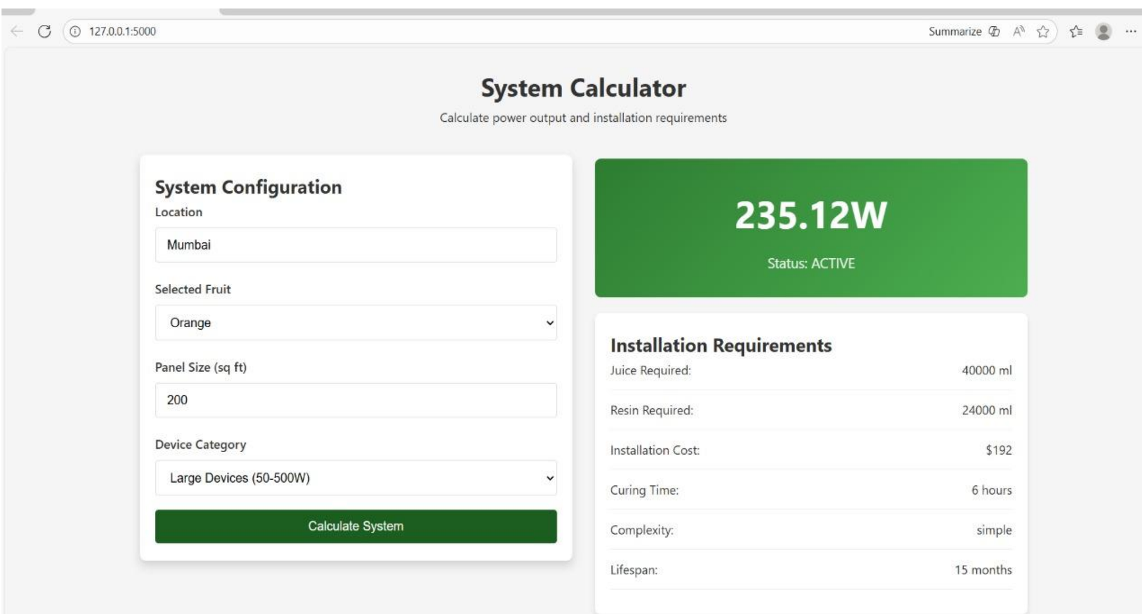
Fruit Recommendation-as per city :-



System Calculator:-



Device Recommendations:-



Annexure – B: Code Snippets

HTML: Welcome Screen

index.html ×

templates > index.html > ...

```html
<!DOCTYPE html>
<head>
    <meta charset="UTF-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Biophotonix</title>
    <style>
        /* Global Styles */
        :root {
            --primary-color: #2e7d32;
```

HTML: City Input Screen

```html
<div id="city-input-screen" class="city-input-screen" style="display: none;">
    <div class="city-panel">
        <h1 class="city-title">Where are you located?</h1>
        <div class="city-subtitle">We'll recommend the best fruit electrolytes for your climate</div>
        <div class="search-row">
            <input type="text" id="city-input" class="search-input" placeholder="Enter city name (e.g.,
            <button id="find-fruits-btn" class="search-btn">Search</button>
        </div>
        <div class="or-divider">or</div>
        <button id="use-location" class="use-location-btn"><span>📍</span> Use my current location</but
        <div class="popular-chips" style="margin-top:18px;">
            <button class="chip" onclick="setCityAndSearch('London')">London</button>
            <button class="chip" onclick="setCityAndSearch('Miami')">Miami</button>
            <button class="chip" onclick="setCityAndSearch('New York')">New York</button>
            <button class="chip" onclick="setCityAndSearch('Tokyo')">Tokyo</button>
            <button class="chip" onclick="setCityAndSearch('Sydney')">Sydney</button>
            <button class="chip" onclick="setCityAndSearch('Seattle')">Seattle</button>
        </div>
```

JavaScript: Weather API Fetching Logic:-

```javascript
// Display weather data
function displayWeatherData(weather) {
    weatherInfoElement.innerHTML = `
        <div class="weather-item">
            <div class="weather-value">${weather.temperature}°C</div>
            <div class="weather-label">Temperature</div>
        </div>
        <div class="weather-item">
            <div class="weather-value">${weather.humidity}%</div>
```

App.py -Api Configuration

```python
import math
from datetime import datetime, timedelta
import os
from dotenv import load_dotenv
import logging

app = Flask(__name__)

# API Configuration
API_KEYS = {
    'openweathermap': os.getenv('OPENWEATHER_API_KEY', 'demo_key'),
    'weatherapi': os.getenv('WEATHERAPI_KEY', 'demo_key'),
    'currency': os.getenv('EXCHANGERATE_API_KEY', 'demo_key')
}
```

Energy Calculator page:-

```html
<html lang="en">
<body>
    <h1>System Calculator for {{ city }}</h1>
    <h2>Configuration</h2>
    <p>Selected fruit: {{ fruit.name }}</p>
    <p>Panel size: {{ panel_size }} sq ft</p>
    <p>Device category: {{ device_category }}</p>

    <h2>Weather</h2>
    <p>Data source: {{ weather.provider if weather.provider is defined else 'mock' }}</p>
    <ul>
      <li>Temperature: {{ weather.temperature if weather.temperature is defined else 'N/A' }} °C</li>
      <li>Humidity: {{ weather.humidity if weather.humidity is defined else 'N/A' }}%</li>
      <li>Cloud Cover: {{ weather.cloud_cover if weather.cloud_cover is defined else 'N/A' }}%</li>
      <li>UV Index: {{ weather.uv_index if weather.uv_index is defined else 'N/A' }}</li>
      <li>Climate Zone: {{ weather.climate_zone if weather.climate_zone is defined else 'N/A' }}</li>
    </ul>
```

Reference

• Core Science (Fruit Electricity):
Kalagbor, I. A., & Akpotayire, S. I. (2020). Electricity generation from waste tropical fruits - Watermelon (Citrullus lanatus) and Paw-paw (Carica papaya) using single chamber microbial fuel cells. International Journal of Energy, Information and Communications, 11(2), 11–20. https://gvpress.com/journals/IJEIC/vol11_no2/2.pdf
Supports the feasibility of using fruit electrolytes.
• Scientific Context (Biophotovoltaics Field):
McCormick, A. J., Bombelli, P., Bradley, R. W., Thorne, R., Wenzel, T., & Howe, C. J. (2015). Biophotovoltaics: Oxygenic photosynthetic organisms in the world of bioelectrochemical systems. Energy & Environmental Science, 8, 1092–1109. https://doi.org/10.1039/C4EE03875D
Provides a foundation for the broader scientific field.
• Fruit Waste & Bioelectricity (Opportunity & Solution):
Rodríguez-Valdivieso, V., Zafar, H., Peleato, N., & Roberts, D. (2023). Generation of bioelectricity from organic fruit waste. Environmental Research, Engineering and Management, 80(2), 52–61.
https://erem.ktu.lt/index.php/erem/article/view/28493/15074
Directly supports the concept of utilizing agricultural waste for energy.
• Problem Statement (Global Energy Access):
United Nations. (2023). Goal 7: Affordable and clean energy: Proportion of population with access to electricity, 2015 and 2021. SDG Indicators. https://unstats.un.org/sdgs/report/2023/goal-07/
Credible source for the problem of energy shortages and rural access.
• Technical Implementation (Web Stack):
MDN Web Docs. (2023, November 15). The conceptual foundation of JavaScript. Mozilla Developer Network.
https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Conceptual_foundation
Standard reference for the core technology used to build the simulation.
• Renewable Energy Costs (Market Context/Comparison):
International Renewable Energy Agency (IRENA). (2024). Renewable power generation costs in 2023.
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/IRENA_Power_Generation_Costs_2023.pdf
Useful for comparing the potential low cost of your system against traditional renewables (e.g., solar panels).
• Decentralized Energy Systems (Market Relevance):
World Bank Group. (2023). Mini grids and decentralized power: A guide to policy and regulation.
https://openknowledge.worldbank.org/entities/publication/527d4986-7a4e-51bf-adf4-c58ee57c2f0c
Supports the concept of a portable, off-grid solution relevant to rural households.
• Electrochemical Principles (The pH and Acidity Mechanism):
Bard, A. J., & Faulkner, L. R. (2001). Fundamentals of electrochemistry. In Electrochemical Methods: Fundamentals and Applications (2nd ed., pp. 1–25). John Wiley & Sons.
Provides the underlying scientific principle for why fruit pH and acidity matter for voltage output.