IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 1, April 2026
Impact Factor: 8.2

Smart Hybrid Generation for Universal Application

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Abstract: *The rapid growth of urban populations has led to increased energy consumption, environmental pollution, and the need for sustainable infrastructure. Traditional urban systems are heavily dependent on non-renewable energy sources, leading to inefficiencies and a high carbon footprint. The Smart Urban City – A Sustainable Vision project addresses these challenges by integrating renewable energy harvesting, intelligent automation, and IoT-based monitoring into a cohesive urban model.*

The core feature of this project is the Hybrid Tree, a sunflower-inspired solar tracking system designed to optimize solar energy capture. Using LDR sensors, MG996R servo motors, and an N20 gear motor controlled by an Arduino Nano, the Hybrid Tree can open its solar panels like petals, track the sun's movement throughout the day, and close at night. Energy harvested from the solar panels, along with contributions from micro wind turbines and piezoelectric sensors, is stored in a centralized Power House consisting of an 11.1V Li-ion battery pack with a Battery Management System (BMS) for safe and regulated energy storage.

This project demonstrates the technical feasibility of combining solar, wind, and mechanical energy sources into a hybrid system capable of intelligent energy distribution, automation, and remote monitoring. It highlights the potential of integrating renewable energy, IoT technologies, and automation to create energy-efficient, environmentally friendly, and sustainable urban infrastructure. The prototype serves as a functional model for future smart city development, providing practical insights into energy management, renewable integration, and urban automation...

Keywords: Smart Urban City, Sustainable Infrastructure, Hybrid Energy System, Solar Tracking System, Renewable Energy Integration, IoT-Based Monitoring, Intelligent Automation, Energy Efficiency, Battery Management System (BMS), Hybrid Tree Model

I. INTRODUCTION

With the rapid growth of urbanization, modern cities face increasing challenges in terms of energy demand, environmental pollution, and sustainable infrastructure. Traditional urban systems heavily rely on fossil fuels, leading to a rise in greenhouse gas emissions and resource depletion. To address these challenges, the concept of a Smart Urban City has emerged, integrating renewable energy, intelligent automation, and IoT-based monitoring systems.

Our project, "Smart Urban City – A Sustainable Vision," demonstrates a small-scale prototype of such a city. The primary goal is to create a self-sustainable and energy-efficient system that can harvest renewable energy from multiple sources, store it safely, and utilize it for various urban applications. The central feature of the model is the Hybrid Tree, a sunflower-inspired solar tracking system that opens and closes its solar panels like petals. Using LDR sensors, the Hybrid Tree detects sunlight intensity and direction, enabling the MG996R servo motors and N20 gear motor to rotate the panels optimally throughout the day. This ensures maximum energy capture from the sun.

In addition to solar energy, we integrate wind energy using small wind turbines and mechanical energy harvesting through piezoelectric sensors placed on a foam-board staircase model. All harvested energy is stored in a Power House,

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represented by an 11.1V Li-ion battery pack with BMS protection, which regulates voltage and ensures safe operation. The stored energy powers multiple subsystems such as automatic street lights, IoT air quality monitoring, and a mini EV charging station.

The IoT subsystem uses an ESP8266 Node MCU, which reads data from MQ135 gas sensor and DHT11 temperature and humidity sensor, displaying it on a 0.96-inch OLED screen and transmitting it to the Blynk dashboard for remote monitoring. The system demonstrates intelligent energy management, real-time environmental monitoring, and automation for urban utilities.

This project serves as a model to showcase how renewable energy, IoT, and automation can be integrated to create a sustainable urban environment. It emphasizes the efficient use of resources, reduction of carbon footprint, and the potential of hybrid energy systems to meet the growing demands of modern cities.

II. LITERATURE SURVEY

The development of smart cities and sustainable urban infrastructure has attracted significant attention in recent years, with research focusing on renewable energy integration, automated systems, and IoT-based monitoring. Several studies and practical implementations provide valuable insights for the design of the Smart Urban City prototype.

Solar tracking systems have been widely studied and implemented to improve photovoltaic efficiency. Research indicates that a solar tracking system can enhance energy capture by 30–40% compared to fixed panels. Sunflower-inspired designs, like the Hybrid Tree in this project, are particularly effective, as they allow dynamic adjustment of panel orientation using feedback from light sensors. High-torque servo motors combined with micro DC motors have been shown to provide precise and reliable tracking even under variable light conditions.

Energy storage and management are critical in hybrid renewable systems. Li-ion batteries with integrated BMS circuits are commonly used to ensure safe charging and discharging while supplying stable voltage to multiple loads. Studies have demonstrated that hybrid energy systems, combining solar, wind, and mechanical energy harvesting (e.g., piezoelectric), can significantly enhance energy reliability, particularly for small-scale urban applications. Proper integration of rectifiers, buck converters, and protection circuits ensures efficiency and safety across diverse energy sources.

IoT-based environmental monitoring is another area of extensive research. Low-cost microcontrollers like ESP8266 Node MCU, combined with sensors such as MQ135 and DHT11, provide real-time data on air quality, temperature, and humidity. Cloud-based dashboards like Blynk facilitate remote monitoring, alert generation, and data visualization, which are essential for smart city applications. These systems demonstrate the feasibility of integrating real-time sensing and wireless communication to improve urban environmental management.

Automation in street lighting using LDR sensors and LED modules has been successfully implemented in many projects to reduce energy wastage. Feedback-based control ensures that lights operate only when required, optimizing energy usage and operational cost. Similarly, small-scale EV charging systems powered by renewable energy have been explored in research to demonstrate clean transportation solutions and load management strategies.

The literature emphasizes the importance of combining renewable energy sources, smart control, and IoT integration to create a sustainable urban environment. The Smart Urban City prototype builds upon these insights, incorporating sunflower solar tracking, hybrid energy generation, automated street lighting, IoT-based environmental monitoring, and energy storage into a cohesive and functional model.

III. OBJECTIVE

The primary objective of this project is to design, develop, and demonstrate an integrated Smart Urban City prototype that combines renewable energy harvesting, energy storage, automated control, and IoT-based environmental monitoring to achieve sustainable urban infrastructure. The project aims to address technical challenges in energy efficiency, automation, and real-time monitoring while providing a scalable framework for future smart city applications

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DOI: 10.48175/568
ISSN 2581-9429 IJARSCT

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3.1 The specific technical objectives are as follows:

To engineer a Hybrid Tree (Sunflower Solar Tracker) that employs multiple LDR sensors and high-torque MG996R servo motors in conjunction with an N20 gear motor and L298N driver, enabling precise pan-tilt solar tracking and automated opening/closing of solar panels. The system aims to optimize solar energy capture throughout the day while minimizing energy losses during non-productive periods.

To integrate hybrid renewable energy sources including solar panels, micro wind turbines, and piezoelectric energy harvesters, forming a cumulative energy generation system. This includes electrical interfacing, rectification, and safe routing of variable DC outputs to a centralized energy storage unit.

To develop a Power House using an 11.1V Li-ion 3S battery pack equipped with a Battery Management System (BMS) for overcharge, over-discharge, and short-circuit protection. The Power House will supply regulated power to multiple loads including microcontrollers, servo motors, street lighting, IoT sensors, and auxiliary systems, ensuring stable and safe operation.

To implement intelligent automated street lighting using LDR-based feedback systems and power electronics to dynamically control LED operation based on ambient light conditions, thereby reducing energy consumption and demonstrating practical automation techniques.

To design and deploy an IoT-enabled environmental monitoring system using ESP8266 Node MCU interfaced with MQ135 gas sensors and DHT11 temperature/humidity sensors. Data will be displayed on an OLED screen and transmitted to the Blynk platform for real-time cloud monitoring, enabling remote observation, data logging, and decision-making for urban sustainability.

To prototype a miniature EV charging station powered entirely by harvested renewable energy, demonstrating integration of energy storage, power regulation, and load management for small-scale electric vehicle applications.

Through these objectives, the project seeks to combine theoretical knowledge with practical engineering implementation, showcasing a technically sound, reliable, and replicable approach for sustainable urban infrastructure development.

IV. BLOCK DIAGRAM

The Block Diagram represents the overall architecture of the Smart Urban City prototype, showing the interaction between various subsystems including renewable energy sources, energy storage, control systems, and output devices. It provides a clear understanding of how each component contributes to the functionality of the project.

4.1. Description of the Block Diagram:

1. Hybrid Tree (Sun flower Solar Tracker):

The central renewable energy harvesting system consists of multiple solar panels arranged like petals. LDR sensors detect sunlight intensity and direction, while the MG996R servo motors and N20 gear motor control panel rotation for optimal sun tracking. This system maximizes solar energy capture and supplies DC power to the Power House.

2. Wind Turbine:

Small-scale wind turbines are connected to rectifier circuits to convert AC output to DC. The generated energy is routed to the Power House, supplementing solar energy and contributing to overall efficiency.

3. Piezoelectric Sensors:

Piezoelectric transducers placed on staircase models generate energy from mechanical stress. The harvested energy is converted to DC, rectified, and stored in the Power House.

4. Power House(Battery Storage):

An 11.1V Li-ion battery pack with BMS acts as the central energy storage unit. It receives energy from solar panels, wind turbines, and piezoelectric sensors, and supplies regulated power to multiple subsystems using buck converters where necessary.

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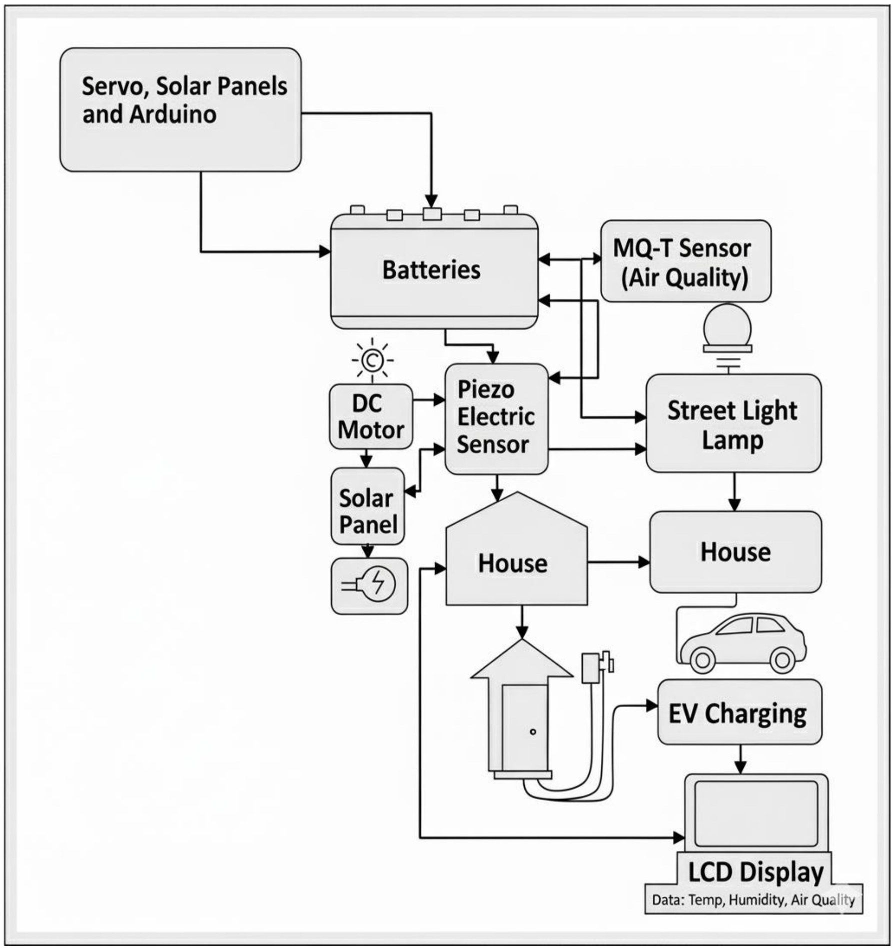


5. Automatic Street Lighting:

LDR sensors detect ambient light levels and control LED modules through the Arduino Nano. Lights turn on automatically during low light conditions and turn off during daylight, optimizing energy consumption.

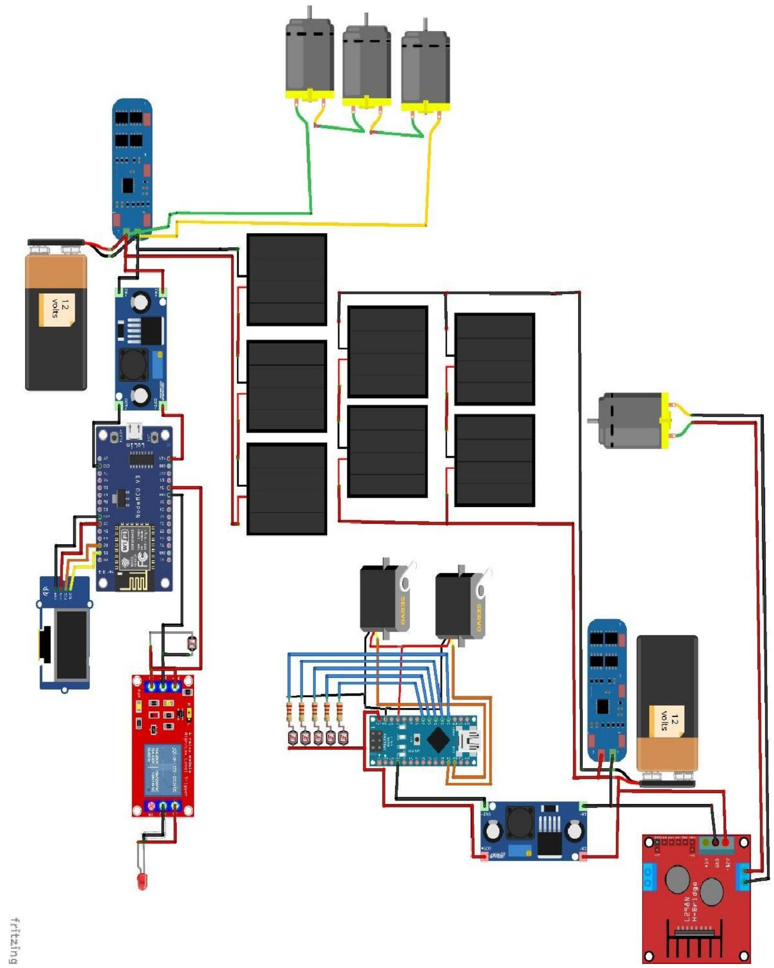
6. IoT Environmental Monitoring:

ESP8266 Node MCU interfaces with MQ135 gas sensor and DHT11 temperature/humidity sensor. Sensor data is displayed on a 0.96-inch OLED display and transmitted to the Blynk IoT dashboard for remote monitoring and logging.

7. Mini EV Charging Station:

A portion of the stored energy from the Power House is used to simulate electric vehicle charging, demonstrating practical utilization of harvested renewable energy.

V. CIRCUIT DIAGRAM



WORKING

The Smart Urban City prototype integrates multiple subsystems including renewable energy harvesting, energy storage, automation, and IoT monitoring. The following describes the working of the circuit in a detailed step-by-step manner:

1. Solar Energy Harvesting (Hybrid Tree):

The Hybrid Tree consists of multiple 0.6W 6V solar panels arranged like petals. LDR sensors are mounted on the petals and the center to detect sunlight intensity and direction.

During daytime, when light falls on the LDRs, their resistance decreases. The Arduino Nano reads the analog voltage corresponding to the LDR resistance.

If the center LDR detects light above a predefined threshold, the Arduino triggers the N20 DC motor via the **L298N motor driver** to rotate the petals counterclockwise until the limit switch indicates full opening.

The MG996R servo motors control pan (horizontal) and tilt (vertical) rotation. They receive PWM signals from the Arduino based on the readings from the side LDRs, ensuring that the panels continuously track the sun.

When sunlight decreases below the threshold (sunset), the Arduino rotates the N20 motor in the clockwise direction to close the petals to the home position. Limit switches provide feedback to stop the motor at the fully closed position.

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2. Energy Storage and Management:
Solar panels, wind turbines, and piezoelectric sensors are connected to the Power House (11.1V Li-ion battery with BMS). Rectifiers convert AC from wind turbines and piezoelectric transducers into DC.
A main fuse (2–5A) is connected in series with the battery positive line for overcurrent protection.
LM2596 buck converters step down the battery voltage to 5V to power the Arduino, ESP8266, and servos safely.
The BMS ensures that the battery is protected against overcharge, over-discharge, and short-circuit conditions.

3. Automatic Street Lighting:
LDR modules detect ambient light levels at street locations. Their output is fed to the Arduino Nano.
The Arduino compares the LDR readings against a threshold to determine day or night.
During low light conditions, the Arduino sends a control signal to switch ON the 1W LEDs through a relay or MOSFET driver circuit. During daylight, the lights are turned OFF automatically.
This ensures energy efficiency and demonstrates an automated control system for urban infrastructure.

4. IoT-Based Environmental Monitoring:
ESP8266 Node MCU reads data from the MQ135 gas sensor for air quality and DHT11 for temperature and humidity.
Sensor readings are processed locally and displayed on a 0.96-inch OLED screen using the I2C protocol.
Simultaneously, data is transmitted via Wi-Fi to the Blynk IoT platform for cloud-based monitoring and visualization.
This allows real-time observation, logging, and remote access, providing a foundation for smart environmental management.

5. EV Charging Station Simulation:
A portion of the stored energy from the Power House is used to demonstrate charging of a miniature electric vehicle model.
Voltage regulation ensures that other subsystems such as the Hybrid Tree, street lighting, and IoT sensors continue to operate without interruptions.This demonstrates practical utilization of renewable energy in transportation applications.

6. Energy Flow Summary:
Energy is harvested from solar, wind, and piezo sources.
It is then routed through rectifiers, protection circuits, and buck converters into the Power House.
From the Power House, regulated energy is supplied to all subsystems according to their voltage and current requirements.
Feedback loops from LDRs, limit switches, and sensors allow automated control and efficient energy utilization.
This step-by-step working demonstrates the seamless integration of mechanical, electrical, and IoT systems into a cohesive Smart Urban City model, showcasing renewable energy optimization, automation, and real-time monitoring.

VI. SOFTWARE REQUIRED

• Arduino IDE :-
Arduino IDE is the primary development environment for programming the Arduino Nano and ESP8266 Node MCU. It allows writing, compiling, and uploading code to the microcontrollers. In this project, Arduino IDE is used to: read LDR and piezo sensor inputs, control servo motors and N20 DC motor, automate street lighting, and interface with the ESP8266 for IoT communication. It supports libraries for sensors, motors, OLED displays, and Wi-Fi modules, simplifying integration of multiple subsystems.

• Tensor Flow :-
Tensor Flow is an open-source machine learning library used for developing and training models. In this project, Tensor Flow can be utilized for predictive analytics, such as forecasting environmental parameters or optimizing solar tracking algorithms. Although primarily for larger datasets, Tensor Flow demonstrates the potential for integrating AI-driven decision-making into urban energy systems.

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• Visual Studio Code :-

Visual Studio Code (VS Code) is a versatile code editor used for writing and debugging code. It supports multiple languages and integrates with Arduino IDE and Python scripts. In the project, VS Code can be used for advanced programming of the Node MCU, debugging sensor data collection, and preparing IoT communication scripts.

• Blynk IoT Platform :-

Blynk is a cloud-based platform for IoT applications. It allows real-time monitoring, control, and visualization of sensor data on mobile devices. In this project, Blynk receives data from the ESP8266 Node MCU, including air quality, temperature, and humidity, and displays it on dashboards. It provides remote access, alerts, and logs, enabling the Smart Urban City prototype to demonstrate IoT-based environmental monitoring.

• Fritzing :-

Fritzing is used for creating circuit schematics and PCB layouts. In this project, it assists in designing the visual representation of connections for the Hybrid Tree, street lighting, IoT sensors, and power management systems. Fritzing simplifies documentation and visualization for educational and prototype purposes.

• Keil :-

Keil IDE is primarily used for ARM-based microcontroller programming. In this project, it can be employed for advanced embedded programming or simulations of motor drivers and sensor interfaces. Although not directly used with Arduino, it provides an engineering environment for testing complex embedded control logic.

• Proteus :-

Proteus is a simulation software used to test circuits virtually before hardware implementation. In this project, Proteus helps simulate the Hybrid Tree solar tracker, servo and DC motor operation, LDR-based automation, and sensor interfacing with microcontrollers. It ensures that the design works as expected and minimizes hardware errors during prototype development.

ADVANTAGES

The Smart Urban City prototype offers multiple technical, environmental, and operational advantages over conventional urban energy and monitoring systems. These advantages include:

Efficient Renewable Energy Utilization:

By integrating solar, wind, and piezoelectric sources, the system ensures continuous and sustainable energy harvesting. The sunflower-shaped Hybrid Tree maximizes solar energy capture through automated sun tracking, resulting in higher energy efficiency compared to stationary panels.

Automation and Smart Control:

The use of LDR sensors, servo motors, and microcontrollers enables automatic operation of solar panels and street lighting without manual intervention. This reduces energy wastage, ensures optimal performance, and demonstrates practical smart city automation.

Environmental Monitoring:

IoT-enabled sensors like MQ135 and DHT11 allow real-time monitoring of air quality, temperature, and humidity. Data is displayed locally on OLED screens and remotely via Blynk dashboards, providing actionable insights for environmental management and urban planning.

Energy Storage and Management:

The Li-ion Power House with BMS ensures safe, reliable, and regulated energy storage. Energy from multiple renewable sources is efficiently stored and distributed to various subsystems, including street lighting and EV charging, ensuring uninterrupted operation.

Scalability and Modularity:

The design of the prototype allows it to be scaled for larger urban applications. Additional renewable sources, sensors, and control units can be easily integrated without redesigning the core system.

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Cost-Effective and Sustainable:
The system uses readily available components, reducing initial costs. Automated energy harvesting and smart control reduce electricity consumption from conventional sources, making it economically and environmentally sustainable.

Demonstration of Hybrid Energy Integration:
The project combines mechanical, electrical, and IoT systems into a single prototype, demonstrating hybrid energy integration. It highlights how different renewable energy streams can work together to power urban infrastructure efficiently.

Educational and Research Value:
The system provides a hands-on learning platform for engineering students and researchers, demonstrating practical applications of renewable energy, IoT, automation, and smart city concepts in a controlled prototype.

VII. CONCLUSION

The Smart Urban City – A Sustainable Vision project successfully demonstrates the integration of renewable energy harvesting, automation, and IoT-based environmental monitoring in a compact and functional prototype. The Hybrid Tree, inspired by the sunflower solar tracking mechanism, effectively captures solar energy by adjusting panel orientation using LDR sensors, servo motors, and a DC gear motor. This system ensures maximum energy generation throughout the day while automatically closing at night to protect the panels.

The Power House, consisting of an 11.1V Li-ion battery with BMS, efficiently stores energy from solar panels, miniature wind turbines, and piezoelectric sensors. The stored energy powers multiple subsystems, including automatic street lighting, IoT environmental monitoring, and a miniature EV charging station. The integration of LM2596 buck converters ensures stable voltage supply to sensitive electronics, maintaining safe and reliable operation.

IoT-based monitoring using ESP8266 Node MCU, OLED display, and Blynk dashboards provides real-time data visualization and remote access, enabling intelligent decision-making for energy usage and urban management. The system showcases how hybrid energy sources, automation, and cloud-based monitoring can coexist in a sustainable urban ecosystem.

Overall, the project demonstrates practical solutions for renewable energy utilization, automated control, and environmental awareness in urban infrastructure. It highlights the potential of combining mechanical, electrical, and IoT systems to develop energy-efficient, environmentally friendly, and sustainable smart cities. The prototype serves as a foundation for future research, scalability, and real-world implementation in urban planning and sustainable development.

REFERENCES

[1]. Patel, K., Patel, S., & Scholar, R. (2017). "IoT based smart agriculture monitoring system." International Journal of Advanced Research in Engineering and Technology (IJARET), 8(5), 154-160. This paper discusses the development of an IoT-based system for monitoring soil parameters like IR and moisture levels for better crop management.

[2]. Al-Garadi, M. A., Mohamed, A., Al-Ali, A. K., Du, X., & Guizani, M. (2018). "A survey of machine and deep learning methods for IoT security." IEEE Communications Surveys & Tutorials, 21(4), 3563-3583. Focuses on the use of IoT sensors and machine learning to optimize irrigation management and reduce water wastage in agriculture.

[3]. Sharma, V., & Singh, J. (2019). "IoT-enabled soil IR monitoring system for agriculture." Journal of Agricultural Sciences, 11(3), 45-50. Explores the role of IoT in monitoring soil IR in real time to optimize crop growth conditions.

[4]. Kaur, J., Sharma, M., & Singh, N. (2020). "Light intensity monitoring system for greenhouses using IoT." Journal of Agricultural Engineering, 45(6), 67-72. A study on using IoT sensors to monitor and control light levels in greenhouses, ensuring optimal growing conditions for plants.

[5]. Iqbal, M., Khan, R., Khan, S., & Iqbal, Z. (2021). "IoT-based temperature and humidity monitoring for greenhouses." Sensors and Actuators A: IRysical, 205(2), 138-145. Describes an IoT-based system for monitoring and controlling temperature and humidity in greenhouses, leading to improved plant health.

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[6]. Jain, A., & Rajesh, M. (2020). "Precision agriculture using IoT and data analytics." International Journal of Scientific Research in Computer Science and Engineering, 8(3), 98-105. This paper covers the application of IoT sensors and data analytics to monitor environmental conditions and optimize irrigation for precision agriculture.

[7]. Ramesh, P., Suresh, G., & Kumar, D. (2019). "IoT-based rain detection system for irrigation scheduling." International Journal of Agriculture and Environmental Research, 5(4), 233-245. Discusses the development of a rain detection system using IoT to assist farmers in scheduling irrigation based on real-time weather data.

[8]. Choudhury, A., Singh, S., & Gupta, R. (2019). "IoT and machine learning for pest detection in agriculture." International Journal of Computer Applications, 182(1), 25-30. Focuses on combining IoT data with machine learning algorithms to predict and detect pest infestations, leading to reduced pesticide usage.

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DOI: 10.48175/568