

Solar Panel System with IoT-Based Control for Dome Dryer in Coffee Production as Support for Sustainable Agrotourism

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ABSTRACT

The necessity of electrical energy in human existence is paramount. The government is presently enacting policies, particularly in the electrical sector, to cultivate alternative energy sources in an effort to diversify energy through regulatory measures, including by establishing solar power plants (SPP) as a form of renewable energy. Solar power plants (SPP) will provide renewable energy to substitute electrical energy for a control system that can be monitored through the Internet of Things (IoT) on dome dryers for coffee drying. Problem Formulation: The cost of power from SPP is perceived as exorbitant; there are challenges in regulating temperature and humidity within the dome drying chamber, leading to significant heat energy wastage; the quality of traditional drying outcomes is inconsistent, resulting in subpar output quality. Research Objectives: Examine the electric current generated by solar energy in accordance with control system specifications. Evaluate external environmental factors affecting the Dome solar dryer; Develop an IoT-based control system; Monitor temperature and humidity within the Dome solar dryer; assess the moisture content of coffee beans processed by the Dome dryer to promote sustainable agrotourism. Applications and Advantages of Research: Implementation of renewable energy technology, particularly solar photovoltaic (PV); provision of practical knowledge and technology regarding the solar dryer dome for the community; Understanding the solar panel system integrated with a remote control (IoT) control system to achieve optimal drying temperatures for coffee; Attaining accurate moisture content in coffee products from dome dryers to promote sustainable agrotourism. Research Method: conducted in phases, specifically observation and the installation of auxiliary equipment for direct data collection in the field (experimental). Research findings indicate that solar panels transform solar energy into electrical energy. Solar

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panels generate direct current (DC) power; they mitigate carbon emissions by producing electricity without releasing greenhouse gases, such as CO₂, which contribute to global warming.

Keywords: Agrotourism, Drayer Dome, Energy, Internet of Things, Solar.

INTRODUCTION

The demand for electrical energy in daily life is crucial, spanning from urban to rural areas. It is utilized not only for illumination and domestic requirements but can also be harnessed for productive enterprises, including large, medium, small, and household industries, thereby enhancing the community's economy. The government is presently enacting policies, particularly in the electricity sector, to harness the potential of alternative energy sources in an effort to diversify energy through regulatory implementation, specifically by advancing solar power plants (SPP) as a form of renewable energy. Renewable energy generated from solar power plants (SPP) will substitute electrical energy from PLN to operate the control system, which can be monitored through the Internet of Things (IoT) on the dome dryer for coffee drying (Rateila, 2023). Coffee is a plantation commodity with significant economic value compared to other crops and serves as a vital source of foreign exchange for the nation. Besides serving as a significant source of foreign revenue, coffee also provides income for farmers, numbering at least one and a half million in Indonesia.

Coffee is essential for humans and has health benefits such as reducing the risk of diabetes, enhancing stamina, alleviating headaches, and improving respiration, among others. Indonesia is among the leading coffee-producing nations, boasting a diverse array of species, which has resulted in a sustained increase in demand for Indonesian coffee (Siregar et al., 2025). In response to the rising demand for coffee in both domestic and international markets, the government would augment coffee plantings in hilly and mountainous regions. Currently, Indonesian coffee is in high demand on the worldwide market, commanding elevated prices and receiving several major prizes. These coffee manufacturers must be capable of producing

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high-quality coffee goods through an effective drying process, ensuring a distinctive specialty appreciated by consumers. Consumers will undoubtedly select high-quality coffee products that are processed hygienically and meet the requisite quality requirements (Sembiring et al., 2024). A coffee product is deemed high quality if it satisfies consumer wants or aspirations. A cup of coffee often undergoes an extensive process, beginning with cultivation, followed by harvesting, post-harvest processing, and ultimately reaching coffee enthusiasts.

High-quality coffee is derived solely from premium coffee beans that undergo meticulous processing. The quality of coffee production significantly influences the elevated selling price due to superior quality standards of coffee products. If a company offers high-quality coffee items, it will attract new consumers. Problem Formulation: The utilization of electricity from solar power plants is deemed prohibitively costly; traditional drying methods are time-consuming and yield suboptimal, unhygienic results; there are challenges in regulating temperature and humidity within the dome drying chamber, leading to significant heat energy wastage; the quality of outcomes from traditional drying is inconsistent, resulting in inferior production quality.

The Solar Dryer Dome is a dome-shaped drying apparatus resembling a greenhouse incubator, akin to a solar tunnel. The primary distinction lies in the covering material; greenhouses and solar tunnels typically utilize polyethylene terephthalate (PET), whereas solar dryer domes employ polycarbonate (Gunawan et al., 2022). The elevated temperature in the Dome drying room can expedite the drying process of the product, aided by solar photovoltaics and exhaust fans that enhance air circulation, facilitating moisture removal and mitigating humidity that could compromise the tissue structure of the dried material. The benefit of this dome solar dryer is in its ability to efficiently and hygienically dry objects, ensuring a rapid and effective drying process. Conversely, the application of polycarbonate coverings on sun dryer domes can safeguard items against UV radiation that may compromise product attributes, including color, chemical composition, scent, flavor, and overall quality.

RESEARCH LABORATIONS

The research material consists of wet coffee beans designated for drying. This research was conducted in multiple phases, including observation and the installation of supporting equipment for direct data collection in the field (experimental), followed by data analysis. Elucidate the significance of renewable energy and the utilization of Internet of Things (IoT) technologies in agrotourism. Assess deficiencies in the current coffee drying system and explore prospects for enhancing efficiency via the implementation of solar panels and Internet of Things (IoT) technology (Budiman et al., 2022). Develop and execute a solar panel system featuring IoT-based control for a dome dryer utilized in coffee processing. Assess system efficacy within the framework of sustainable agritourism.

Perform a literature review concerning solar panel technologies, the Internet of Things (IoT), and coffee drying systems. Gathering data and insights on IoT applications in drying systems and the advantages of solar panels in agrotourism. Developing a dome drying method for coffee with solar panels as the primary energy source. Creating an IoT-driven control system to enhance the drying process. Installing solar panels and Internet of Things gadgets on the dome dryer. Evaluating system performance in actual operational environments. Gathering system performance metrics, encompassing energy efficiency, drying duration, and quality of drying outcomes. Employing sensors and IoT devices to assess environmental and operational metrics.

RESULTS AND DISCUSSION

Evaluating electric current generated by solar energy in accordance with the requirements of the control system. According to the regulations set forth by the Minister of Energy and Mineral Resources, rooftop solar power plants (SPP) involve the generation of energy by photovoltaic modules installed on the roofs, walls, or other sections of buildings owned by consumers or the community. Typically, Solar Power Plants (SPP) installed on roofs or walls consist of essential systems and components. The operational principle of the rooftop/wall Solar Power Plant (SPP) system is that solar panels transform solar energy into electrical

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energy. Solar panels generate Direct Current (DC), which is subsequently converted into Alternating Current (AC) via an inverter. The AC is then integrated into the electricity network within the solar dryer dome through the AC breaker panel. Electrical energy is utilized for illumination and electronic devices in the control system of the solar dryer dome. Additionally, kWh import-export (exim) meters are employed within a net metering framework. The exim meter measures electricity exports from SPP customers to the SPP network and imports from the SPP network to SPP customers, establishing a connection with PLN. All of these components collaborate to transform solar energy into electrical energy suitable for use in solar dryer domes or for distribution to the public electricity grid. In certain instances, the Solar Power Plant (SPP) system may be linked with additional energy sources, such as grid electricity or generators, to provide a reliable and continuous energy supply. Similar to numerous fossil fuel-based initiatives, the establishment of renewable energy plants necessitates land use. The land requirements differ among various forms of renewable energy. To delineate the land needs for diverse energy systems, encompassing both electricity generation and fuel production.

Environmental Considerations: Solar Power Plants (SPP) exert various effects on the environment. As a renewable energy source, SPP offers numerous advantages over conventional energy sources like fossil fuels; yet, it also has several consequences that warrant consideration. Among the beneficial effects of SPP are reduced carbon emissions: SPP produces power without releasing greenhouse gases like CO₂, which contribute to global warming. SPP greatly mitigates greenhouse gas emissions by decreasing fossil fuel consumption. The decrease in carbon emissions will evidently transpire with the implementation of PLTS, provided that the electrical supply in the region previously relied on oil-fueled generators. Absence of Direct Emissions: A primary advantage of SPP is their lack of direct emissions during operation. PLTS turns solar energy into electricity without fuel combustion, hence producing no greenhouse gas emissions, including CO₂. . Additionally, solar power plants (SPP) can serve as substitutes for fossil fuel-based power plants, such as coal-fired or natural gas facilities. Minimizing fossil fuel consumption can substantially decrease carbon emissions from the energy sector; Advocacy for Clean Energy: Embracing photovoltaic and other renewable energy sources enables communities to transition to a cleaner and more sustainable energy portfolio, thereby ultimately diminishing carbon emissions; Endorsement of Climate Policy: Governments and international organizations frequently

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promote renewable energy utilization as a component of global initiatives aimed at reducing carbon emissions. Establishing Solar Power Facilities. can assist nations in attaining emission objectives established in climate accords; Enhanced Energy Efficiency: The ongoing advancement of solar power plant technology will positively influence the efficacy of converting solar energy into electricity. Solar power plants can generate increased electricity from the same sunlight, thereby minimizing the necessity for supplementary resources. Additionally, these plants can be integrated with energy storage systems, such as batteries, to accumulate energy produced during daylight and utilize it during periods of darkness. This addresses the issue of variability in energy generation and optimizes the utilization of renewable energy sources.

Developing a remote control system utilizing the Internet of Things to monitor and regulate solar heat for electrical power generation, while simultaneously measuring temperature and humidity within a solar dryer dome, employing a data logger based on the Arduino Uno microcontroller in the drying chamber.

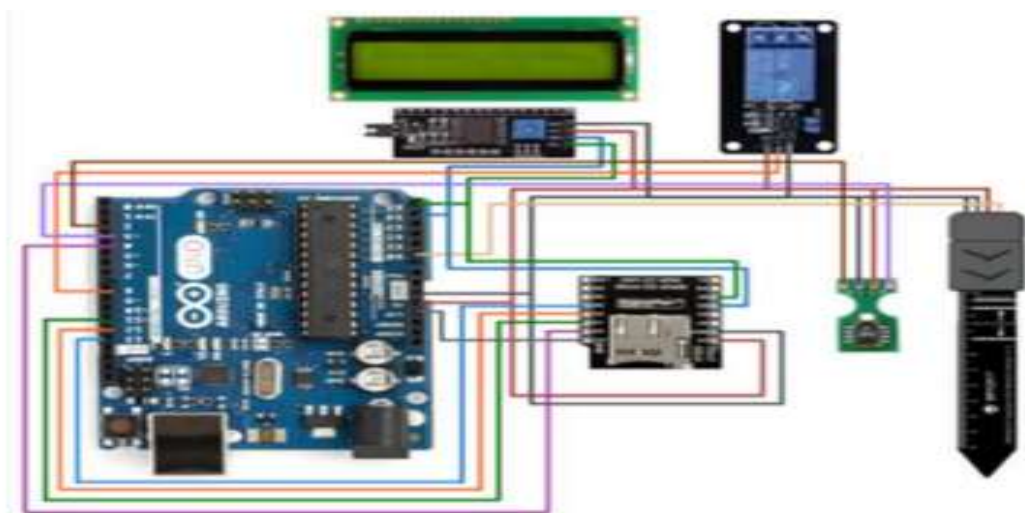


Figure 1. Temperature and Humidity Control Circuit

The remote control system (Internet of Things) facilitates the acquisition of temperature and humidity data in the dome drying room through a data logger utilizing the SHT10 sensor as the input source. The data is subsequently processed by the Arduino Uno microcontroller,

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serving as a control center, in conjunction with the Wemos D1 Mini component, which is outfitted with an RTC module and micro SD card. The SD module operates as a timer for the data storage procedure into the micro SD. The module displays the results on the LCD. The Arduino Uno microcontroller controls the relay to manage the ON/OFF operation of the exhaust fan based on the humidity readings from the SHT10 sensor. Determining the temperature and humidity within the Dome solar dryer chamber.

Assessing the moisture content of coffee beans processed by the Dome dryer is a crucial aspect in promoting sustainable agrotourism. Various drying procedures influence the moisture content and quality of coffee beans. The effectiveness and cleanliness of outcomes differ between natural drying (direct sunshine) and the combined approach (drying house with ultraviolet plastic cover). The combined method is generally more successful due to a faster drying rate and cleaner results in terms of cleanliness. In sustainable agrotourism, selecting an eco-friendly and efficient drying process is crucial to educate farmers and agrotourism managers on effective drying procedures and the utilization of renewable energy, hence enhancing awareness of sustainability. The incorporation of drying technologies into sustainable agricultural systems can enhance the production of high-quality, eco-friendly coffee. From a philosophical perspective on science, the application of drying technology in agriculture imparts knowledge regarding scientific principles and practices that can enhance sustainability and promote the welfare of both humanity and the environment.

CONCLUSION

From the study's findings and discourse, the following conclusions may be inferred: A solar panel system utilizing renewable energy, a remote control system (Internet of Things) for regulating temperature and humidity in dome-type solar dryers, employing an Arduino Uno as the control center, an SHT10 sensor for measuring temperature and humidity, a relay for controlling the exhaust fan, an LCD for data display, and a Wemos D1 mini data logger with an RTC shield for direct data recording onto a MicroSD card;

The drying process for testing with a dome-type solar coffee dryer yielded findings indicating varying levels of temperature and humidity fluctuations within the drying chamber. At specific locations, the maximum temperature attained was 63.5°F with a minimum humidity of 12.6%, whereas the minimum temperature recorded was 20.6°F with a maximum humidity of 85.4%. This condition influences the efficacy of coffee drying, resulting in an expedited process at elevated temperatures and reduced humidity.

The utilization of an exhaust fan regulated by an air humidity controller is vital in sustaining optimal conditions within the drying chamber, thereby inhibiting the proliferation of fungal pests and microorganisms that compromise coffee quality. The dome-type solar dryer is highly successful in elevating drying temperatures and decreasing humidity within the drying chamber, hence optimizing coffee drying. The author suggests that future study should include the incorporation of batteries into the solar panel system to ensure the exhaust fan on the solar dryer dome operates optimally and continuously until nightfall. This is to provide enough air circulation during the drying process, which can influence the efficacy and quality of the drying outcomes.

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