

Solar Powered Air Purifier with Air Quality Monitoring and Carbon Credit Generation

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ABSTRACT: -

Air pollution poses a severe threat to public health and the environment due to the presence of pollutants such as PM_{2.5}, PM₁₀, NO_x, CO, and volatile organic compounds (VOCs). Conventional air purification systems are primarily limited to indoor environments and lack scalability for outdoor applications. This paper proposes a solar-powered outdoor air purification system integrated with real-time air quality monitoring. The system operates using renewable solar energy, ensuring sustainable and energy-efficient performance. A multi-stage filtration mechanism, comprising HEPA filters, activated carbon, and photocatalytic oxidation layers, is employed for effective removal of particulate matter and gaseous pollutants. An IoT-enabled sensing module continuously monitors key air quality parameters and computes the Air Quality Index (AQI). The collected data is transmitted to a cloud-based platform for real-time analysis, visualization, and public accessibility. Furthermore, the system incorporates a carbon credit generation framework based on quantified pollutant reduction metrics, enabling potential economic benefits. The proposed solution offers a scalable, cost-effective, and environmentally sustainable approach to improving outdoor air quality and supporting climate action initiatives.

Keywords— Air Pollution, Solar Energy, Air Purifier, IoT, Air Quality Monitoring, AQI, Carbon Credits, Sustainable Systems, Smart Environment, Renewable Energy.

INTRODUCTION: - Air pollution has emerged as one of the most critical environmental and public health challenges of the 21st century, driven by rapid industrialization, urbanization, and population growth. Pollutants such as PM_{2.5}, PM₁₀, NO_x, SO_x, CO, and VOCs significantly degrade air quality and

contribute to severe health issues including respiratory and cardiovascular diseases. While conventional air purification systems are effective indoors, they are not suitable for large-scale outdoor environments and often depend on non-renewable energy sources.

To address these limitations, a solar-powered outdoor air purifier integrated with real-time air quality monitoring is proposed as a sustainable solution. The system utilizes renewable solar energy to operate multi-stage filtration units capable of removing particulate matter and harmful gases. Additionally, IoT-based sensors continuously monitor air quality parameters and provide real-time data for public awareness and analysis. This approach not only improves localized outdoor air quality but also supports sustainable urban development through clean energy utilization and smart inspection monitoring



2. Solar Powered Air Purifier Components and manufacturing process

The proposed purifier is built around five integrated modules: renewable power generation, air filtration, air circulation, sensing and monitoring, and IoT-based communication.

(1) Solar PV Panels with Charge Controller and Battery Storage:- The system uses solar photovoltaic (PV) panels as the primary power source, with high-efficiency modules mounted on top for maximum sunlight exposure. A charge controller regulates power flow and protects the battery from overcharging

and deep discharge. Energy is stored in rechargeable batteries to ensure continuous operation during night or low sunlight conditions. The solar-based design eliminates dependence on grid electricity, enhancing sustainability. Additionally, the generated solar energy contributes to carbon credit generation by reducing CO₂ emissions associated with conventional power sources..



(2) Filtration Unit (HEPA + Activated Carbon + UV Sterilization + Ionizer):

The air purification unit uses a multi-stage filtration system consisting of a pre-filter, HEPA filter, activated carbon filter, UV sterilization, and an ionizer. The pre-filter removes large particles like dust and pollen, while the HEPA filter captures fine particles such as PM2.5 and PM10. The activated carbon filter adsorbs harmful gases, VOCs, and odors, and UV sterilization neutralizes bacteria and pathogens. The ionizer releases negative ions to improve air freshness and help in clustering fine particles for easier removal. The system reduces harmful pollutants and, when powered by solar energy, contributes to emission reduction and supports carbon credit benefits.



(3) Energy-Efficient Brushless DC (BLDC) Fans for Air Circulation:

For effective purification, BLDC fans are incorporated to draw polluted outdoor air into the unit and circulate clean air back into the environment. BLDC motors are chosen due to their high efficiency, low noise, and long lifespan

compared to conventional AC motors. These fans are optimized for low energy consumption to ensure maximum operation from solar energy reserves. Energy-efficient fans directly reduce power consumption, which minimizes the required solar panel size and battery capacity. This makes the system more resource-efficient and sustainable. Additionally, the avoided grid electricity consumption contributes directly to the calculation of CO₂ savings for carbon credit certification



(4) Air Quality Sensors for Pollutants (PM2.5, PM10, CO₂, NO_x, SO_x, VOCs):

Design Approach: A network of digital sensors is integrated into the purifier to continuously measure air quality. These include:

- Laser-based particulate matter sensors for PM2.5 and PM10.
- NDIR (Non-Dispersive Infrared) sensors for CO₂ measurement.
- Electrochemical sensors for gases like NO_x, SO_x, and VOCs.

The sensors are calibrated for accuracy and reliability, and data is sampled at fixed intervals (e.g., every 1–5 minutes). Carbon Credits Integration: Sensor data provides quantifiable, verifiable evidence of pollutant reduction and CO₂ levels. Such verifiable monitoring is essential for carbon markets, which require transparency and third-party validation. The recorded air quality improvements, combined with renewable energy data, form the evidence base for claiming carbon offset credits.



(5)Integrated: ESP32 microcontroller + Carbon Credit Calculator:- the ESP32 and the Carbon Credit Calculator (software algorithm) are tightly connected to form a smart environmental monitoring and evaluation unit.

The SDS011 sensor measures PM2.5 and PM10 levels in the air. This real-time pollution data is sent to the ESP32. ESP32 reads sensor values, filters noise (basic processing), stores and prepares data for further analysis. Data Processing (ESP32 → Calculator) ESP32 continuously tracks: Pollution before purification, Pollution after purification, Operating time of purifier. This processed data is passed to the Carbon Credit Calculator algorithm. Carbon Credit Calculation (Software Logic) The calculator uses inputs from ESP32 to estimate environmental impact: $\text{Pollutant reduction} = \text{Initial PM} - \text{Final PM}$

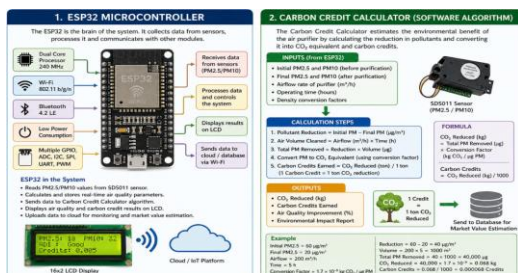
$$\text{Air volume cleaned} = \text{Airflow} \times \text{Time}$$

$$\text{Total pollutants removed} = \text{Reduction} \times \text{Volume}$$

Then it converts this into CO₂ equivalent reduction. Carbon credits earned

(1 carbon credit ≈ 1 ton of CO₂ reduction)

Output & Communication (ESP32 Role Again) After calculation, ESP32 displays results on LCD (16×2) PM levels, Air quality status, Carbon credits. Sends data via Wi-Fi for Cloud storage, Market value estimation.



(6)Market value estimator and display:- the Market Value Estimator and the 16×2 LCD Display, which

work together to calculate and present carbon credit information. The Market Value Estimator is a software-based module that determines the financial value of carbon credits by using pollution data, such as CO₂ emissions, and combining it with current carbon market prices stored in a database or fetched through an API. It processes the emission data received from sensors via the microcontroller and converts it into carbon credits, which are then multiplied by the market price per ton to obtain the final monetary value. This calculated result is then sent to the 16×2 LCD display, which acts as the output interface of the system. The LCD shows real-time information such as CO₂ credit value, price per ton, or system status in a simple and readable format. Together, these components enable the system to not only compute the environmental impact in economic terms but also present it clearly to the user.



3. Block diagram and working principal



WORKING PRINCIPAL

The working principle begins with the solar panel (200 W, 18 V), which converts sunlight into electrical energy. This energy is fed into an MPPT charge controller, which optimizes the power output and regulates the charging process to efficiently charge the 12 V, 7 Ah battery. The battery acts as an energy storage unit and supplies a stable DC power source to the system, including the aerosol-based air purifier (12 V DC).

When powered, the air purifier starts cleaning the surrounding air, and the SDS011 sensor continuously measures air quality parameters such as PM2.5 and PM10 levels. These sensor readings are sent to the ESP32 microcontroller, which processes the data in real time. The ESP32 then forwards this processed data to the carbon credit calculator (software algorithm), which estimates the amount of pollution reduced or controlled and converts it into equivalent carbon credits.

These calculated carbon credits are then passed to the market value estimator (database), which determines their monetary value based on current carbon pricing. At the same time, the ESP32 sends relevant information such as air quality levels, carbon credits, and their market value to the 16×2 LCD/LED display, allowing the user to monitor the system output in real time. Thus, the system integrates solar energy utilization, air purification, environmental monitoring, and economic evaluation into a continuous and automated process.

4. Advantages

1. Uses Renewable Energy
2. Zero Electricity Cost
3. Environmentally Friendly
4. Portable & Easy to Install
5. Supports Green Technology Initiatives
6. Low Maintenance
7. Reduces Air Pollution Exposure
8. Works During Power Cuts
9. Long Lifespan
10. Ideal for Remote or Off-Grid Areas

5. Disadvantages

1. Depends on Sunlight
2. Limited performance on cloudy days
3. Requires Space for Solar Panels
4. Needs proper placement with good sunlight

5. Battery Maintenance
6. Battery replacement (every few years)

6. Applications

1. Homes and Residential Areas
2. Schools and Educational Institutions
3. Hospitals and Clinics
4. Offices and Commercial Buildings
5. Rural and Off-Grid Locations
6. Outdoor Public Spaces
7. Disaster Relief Camps
8. Vehicles and Transport
9. Industrial and Construction Sites
10. Smart City Projects

7. CONCLUSIONS: -

an attempt has been made to systematically design, analyze, build solar-powered air purifier with air quality monitoring and carbon credit generation system provides an efficient, sustainable, and innovative solution to address increasing air pollution. The project also provided an opportunity for multi-disciplinary team to work together and understand the interactions. The teams also have been able to document the lessons learnt to be further used in the upcoming aerospace projects by the same team.

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