SOLAR DRIVEN AIR CLEANSER: SUSTAINABLE SOLUTIONS FOR INDOOR AND OUTDOOR AIR QUALITY

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Keywords

Solar-powered air purifier, Renewable energy, Air quality monitoring, Particulate matter (PM2.5, PM10),HEPA filter, Activated carbon filter, Real-time sensors, Arduino Uno, MQ sensors (MQ135, MQ2, MQ9),DHT sensor, Air Quality Index (AQI),Carbon monoxide (CO),Volatile organic compounds (VOCs), Energy independence, Environmental sustainability, Portable and user-friendly design, Automation, Off-grid operation, Public health, Climate change mitigation, Cost-effective solution

Introduction

Air pollution has become a pressing global concern, with far-reaching implications for both environmental stability and public health. The rapid growth of urbanization, coupled with the relentless expansion of industrial activities, has significantly escalated the concentration of harmful pollutants in the atmosphere. These pollutants, including particulate matter (PM2.5 and PM10), volatile organic compounds (VOCs), toxic gases, and airborne pathogens, pose serious risks to human well-being and disrupt ecological balance. The urgency to address this issue has never been greater, and it calls for innovative, sustainable, and efficient solutions to mitigate the adverse effects of air pollution. This project focuses on the development of a solar-driven air purifier, a revolutionary eco-friendly device aimed at tackling the growing challenge of air pollution. Unlike conventional air purification systems that rely on electricity from fossil fuels, this advanced purifier harnesses the abundant and renewable energy of the sun. By utilizing solar power, the device operates independently of conventional energy grids, making it an energy-efficient, cost-effective, and environmentally sustainable solution. This approach not only reduces reliance on non-renewable energy sources but also aligns with global efforts to combat climate change and promote renewable energy adoption. The solar-powered air purifier integrates cutting-edge technologies to deliver optimal performance. One of its standout features is real-time air quality monitoring, which provides users with accurate, instant feedback on the quality of the surrounding air. This feature empowers users to make informed decisions about their environment and ensures the purifier operates at maximum efficiency when needed. The device also incorporates a sophisticated three-layer filtration mechanism, designed to address a wide range of pollutants comprehensively. The first layer, a High-Efficiency Particulate Air (HEPA) filter, captures fine particulate matter, including PM2.5 and PM10, which are known to penetrate deep into the lungs and pose serious health risks. The second layer consists of an activated carbon filter, which effectively absorbs harmful gases, odors, and VOCs, ensuring the air is free from toxic chemicals. The final layer utilizes photocatalytic oxidation technology, which breaks down airborne pathogens such as bacteria and viruses, further enhancing the air's purity. Department of Electrical and Electronics Engineering, SJBIT Page 1 Solar Driven Air Cleanser 2024-25 Designed with versatility and ease of use in mind, the solar-driven air purifier is both portable and adaptable, making it suitable for a wide range of applications. Its compact and lightweight design allows it to be easily transported and deployed in various settings, including homes, offices, schools, hospitals, and public spaces. Additionally, its robust construction makes it ideal for outdoor environments, where air pollution levels can be particularly high. The purifier’s user-friendly interface ensures that individuals of all ages can operate the device with ease, further enhancing its appeal and practicality. Beyond its immediate impact on air quality, this initiative embodies a broader commitment to environmental preservation and sustainable development. By integrating renewable energy into its design, the solar-driven air purifier serves as a model for environmentally responsible innovation. It encourages the adoption of green technologies and raises awareness about the importance of reducing carbon footprints in everyday life. Moreover, the project highlights the critical role of renewable energy in addressing global challenges, such as air pollution and climate change, while paving the way for a healthier and more sustainable future. In conclusion, the solar-driven air purifier represents a groundbreaking step forward in the fight against air pollution. By combining advanced filtration technology with the sustainable use of solar energy, this innovative device offers a practical, efficient, and eco-friendly solution to one of the most urgent problems of our time. Its ability to provide clean air, promote renewable energy utilization, and support environmental preservation underscores its significance as a transformative tool in the pursuit of a greener, healthier planet.

Figure 1: Introduction

Objectives:

1. **Achieve Energy Independence**

- Develop a solar-powered system capable of autonomous operation, reducing reliance on conventional power sources.

- Ensure uninterrupted functionality through efficient solar energy capture and storage, promoting sustainability and reducing carbon emissions.

2. Enhance Air Purification

- Integrate a dual-layer filtration system combining HEPA and activated carbon filters to effectively remove particulate matter, harmful gases, and airborne pathogens.
- Deliver cleaner, healthier air through comprehensive pollutant removal and sterilization.

3. Real-Time Monitoring

- Equip the system with advanced air quality sensors to detect pollutants and display real- time data.
- Provide a user-friendly interface and connectivity for actionable insights and remote monitoring.

4. Portability and Versatility

- Design a compact, portable air purifier with castor wheels for easy deployment in various settings.
- Ensure adaptability for both indoor and outdoor applications, supported by a durable and user-friendly design.

Methodology:

1. Problem Definition:

   Examine the increasing air pollution in urban areas, focusing on Bangalore.

   Highlight the health impacts of pollutants (PM2.5, PM10) and harmful gases.

Emphasize the need for sustainable and cost-effective air purification solutions.

2. Pre-Analysis of Air Quality:

   Conduct air quality assessments in key areas of Bangalore (industrial, traffic, residential).

   Measure pollutants like PM2.5, PM10, VOCs, CO, and NOx.

   Identify pollution hotspots and prioritize intervention areas.

   Analyse seasonal pollution trends to tailor solutions.

3. Objective Framing:

   Develop a solar-powered air purifier to reduce reliance on non-renewable energy.

   Incorporate advanced filtration mechanisms to eliminate various pollutants.

   Enable real-time air quality monitoring with accessible data.

   Ensure the system is portable, lightweight, and adaptable for different environments.

4. Literature Review:

   Study existing solar-powered air purifiers and IoT-based air monitoring systems.

   Evaluate the effectiveness of different filtration methods like HEPA and activated carbon filters.

   Identify challenges in previous designs (solar efficiency, high costs, and environmental constraints).

   Explore gaps in current solutions to find areas for innovation.

5. System Design and Planning:

Design a solar-driven air purifier based on air quality assessments and research.

Plan for a dual-layer filtration system, solar components, IoT monitoring, and a user-friendly interface.

Address challenges like portability, durability, energy efficiency, and affordability.

6. Prototype Development and Testing:

Develop a functional prototype incorporating HEPA, activated carbon filters, and solar power.

Test the prototype in various environments, including high-pollution zones.

Evaluate filtration efficiency, energy autonomy, durability, and user experience.

Gather feedback from testing to refine the system.

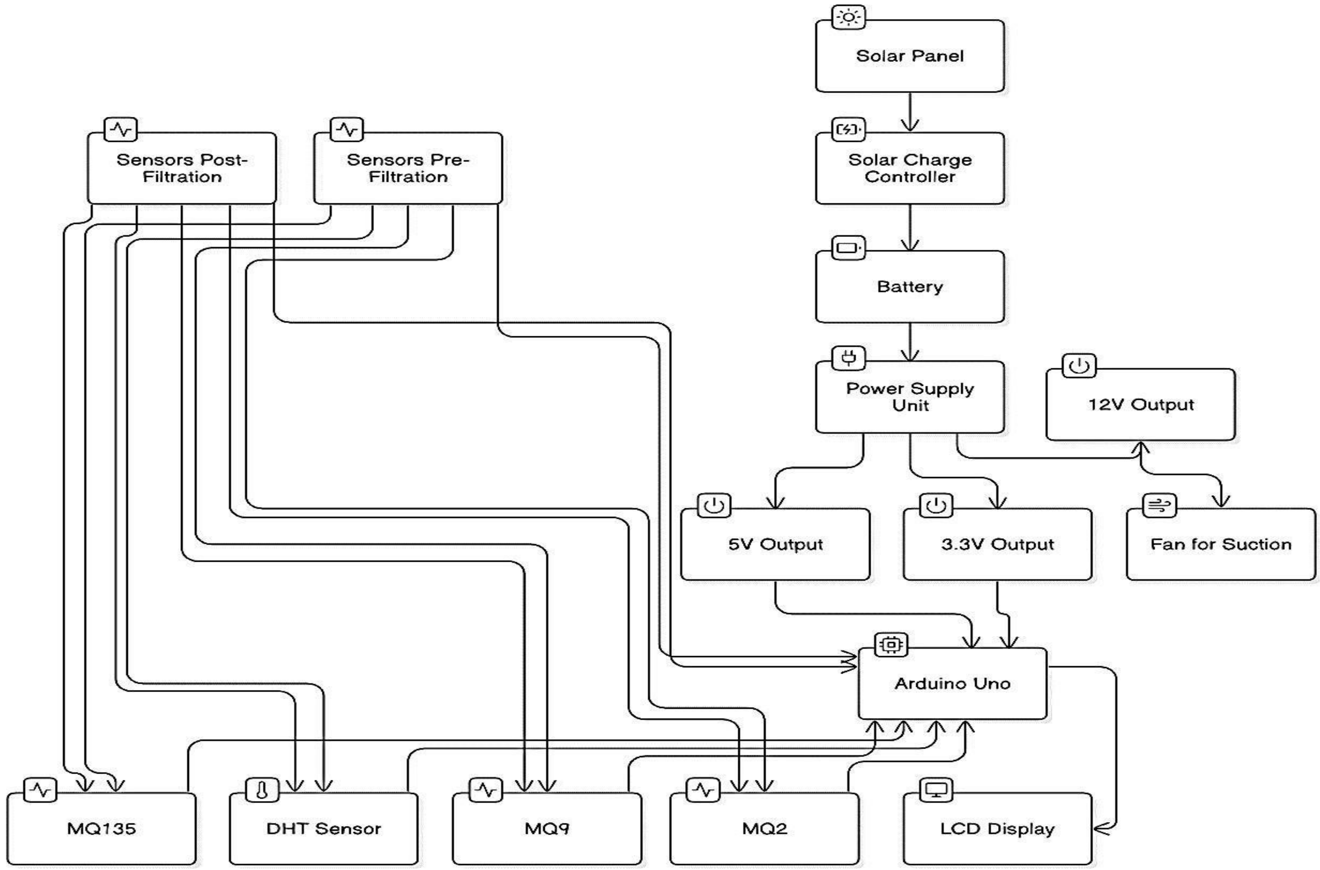

Figure 2 Block Diagram

System Integration:

- The system integration process was a fundamental part of the project, ensuring that all components worked together harmoniously and efficiently to provide optimal performance.

- Energy Storage and Supply Integration: The solar panel was connected to a charge controller to regulate the amount of energy going into the rechargeable battery. This prevents overcharging and ensures the battery is efficiently charged. The charge controller protects the battery from potential damage caused by excessive current or voltage. The battery is, in turn, connected to the rest of the system, providing power to all components, including the blower, filtration system, and sensors. This system ensures continuous operation and autonomy.
- Efficient Power Distribution: A circuit was carefully designed to ensure that power is distributed efficiently from the battery to the different components. Voltage regulators were used to ensure that the components receive the appropriate voltage (5V for sensors and 12V for the fan and filters), thus optimizing their operation and preventing damage. The system was designed with low power consumption in mind, ensuring the purifier runs efficiently, even in areas with limited sunlight.
- Automatic Activation of the Purifier: The air quality sensors were programmed to detect pollutant levels and trigger the activation of the fan and filtration mechanism when pollutant levels exceed predefined thresholds. This automatic activation ensures that the air purifier operates only when necessary, thereby conserving energy and extending the lifespan of the system components. Additionally, the system was programmed to display real-time air quality data on the LCD, allowing users to monitor air quality levels and confirm the system's performance.

Prototype Assembly:

- Once the components were selected and integrated, the focus shifted to assembling the prototype and ensuring that the system was functional, user-friendly, and portable.

- Component Mounting: The components, including the filters, sensors, solar panel, and battery, were carefully mounted onto a portable framework with castor wheels. These wheels enable the system to be easily moved and deployed across various environments, from residential areas to industrial zones. The portable design was essential to ensuring that the system could be used in multiple locations where air pollution levels may vary.
- Ergonomics and User-Friendly Operation: The LCD display was placed in an accessible location on the frame to provide clear visibility of the air quality data. User controls were also integrated into the system, ensuring that users could easily adjust settings, monitor performance, and troubleshoot any potential issues. The controls were designed to be intuitive, reducing the need for technical knowledge and making the system easy for anyone to operate.

Testing and Validation:

- Testing and validation were critical steps in ensuring that the system met its objectives and performed reliably under real-world conditions.
- Field Testing in Varying Environments: The air purifier was tested in multiple locations with different air pollution levels, such as industrial zones, busy traffic areas, and residential neighbourhoods. These tests were conducted to evaluate the purifier's efficiency in removing particulate matter and gases. The system's ability to perform under diverse conditions was key to validating its overall effectiveness.
- Solar Charging Performance Testing: The solar charging performance was closely monitored to verify the system's energy independence. Tests were conducted to determine how well the system could charge the battery under varying sunlight conditions, including bright sun, cloudy weather, and night-time. This helped ensure that the system could reliably operate even in areas with less-than-optimal sunlight.
- Portability and Deployment Testing: The prototype was also tested for ease of

movement and deployment. The castor wheels provided flexibility, allowing the system to be moved across different terrains. The design was evaluated for portability in both outdoor and indoor environments, ensuring that the system could be used effectively in various settings.

Result:

- Effective Air Purification: The system efficiently removes pollutants like PM2.5, PM10, CO_2, CO, and VOCs using a dual-layer filtration (HEPA + activated carbon), improving air quality in indoor and outdoor environments.
- Energy Independence: Powered entirely by solar energy with a rechargeable battery, the purifier operates off-grid, reducing electricity costs and supporting sustainability.
- Real-Time Monitoring: Built-in sensors continuously track air quality and display data on an LCD screen. The system activates automatically when pollution exceeds safe levels, ensuring efficient use of energy.
- Portability and Usability: Lightweight with wheels and a user-friendly interface, the purifier is easy to move and operate, making it ideal for homes, offices, and public spaces.

Conclusion:

- The solar-driven air purifier successfully addresses the challenge of air pollution using **renewable solar energy**, making it both eco-friendly and cost-effective.
- Its **dual-layer filtration system** (HEPA + activated carbon) efficiently removes fine particles, gases, and odors, improving air quality significantly.
- The system's **real-time monitoring** enables automatic activation based on pollution levels, ensuring energy efficiency and reliable performance.

- Designed for **portability**, it can be used in various indoor and outdoor settings including homes, offices, and industrial areas.
- Operating fully **off-grid**, it is ideal for areas with limited electricity access.
- The **user-friendly interface** makes it easy to use for all age groups, encouraging wider adoption of clean air solutions.
- Overall, the project demonstrates a scalable, sustainable approach to improving public health and promoting environmental responsibility.

Future Scope:

1. **Improved Energy Storage:**

   Use advanced battery technologies (e.g., lithium-ion, supercapacitors) to enhance energy storage, offering higher efficiency, faster charging, and longer lifespan, ensuring uninterrupted operation even during low sunlight.

2. **Enhanced Filtration Systems:**

   Integrate additional filtration technologies like activated alumina for better gas removal and UV-C sterilization to eliminate pathogens, ensuring both pollutant-free and hygienically safe air.

3. **IoT Integration for Remote Monitoring:**

   Enable smart capabilities through IoT, allowing remote monitoring and control, real-time performance tracking, and remote troubleshooting, enhancing system maintenance and user convenience.

4. **Scalability for Larger Applications:**

   Scale the system for industrial and commercial use, allowing for larger units and multi-unit networks, enabling centralized control and optimal air quality in diverse spaces like factories, offices, and public areas.

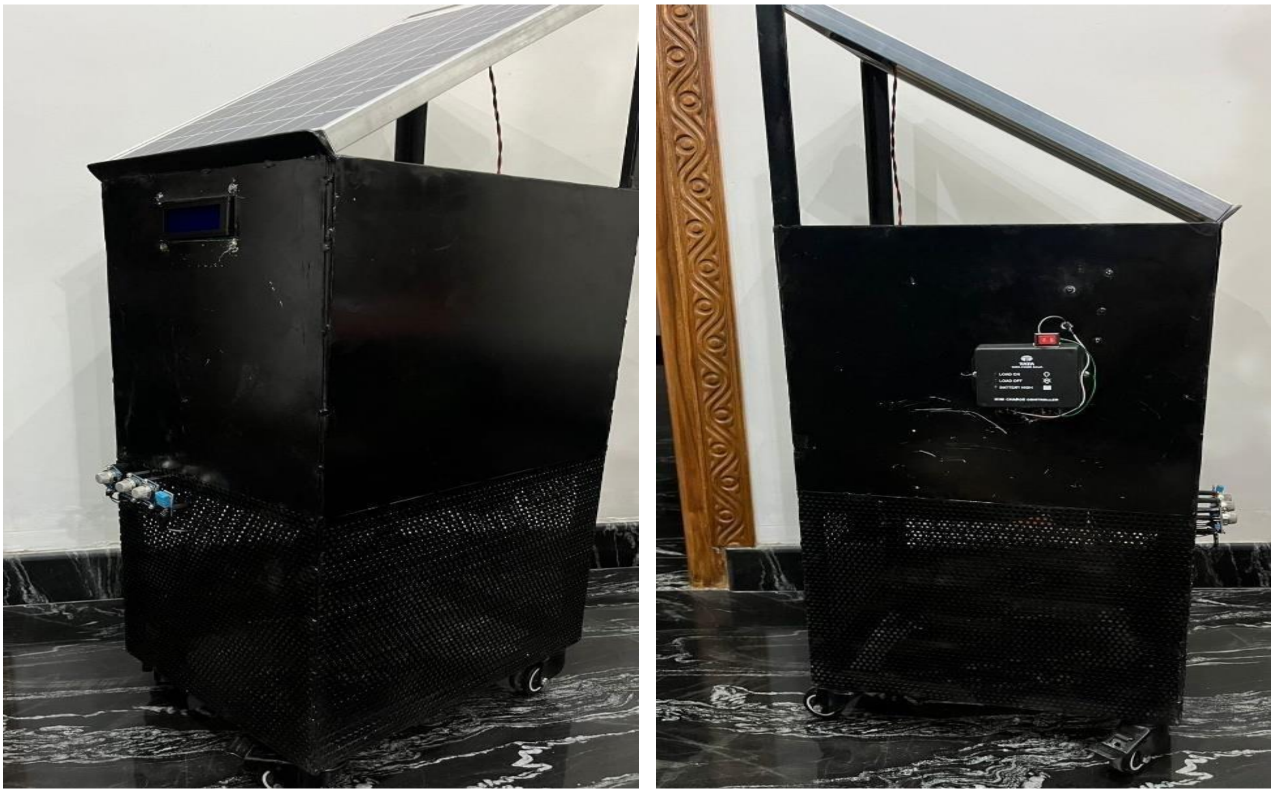

Figure 3 & 4 Working Model

Figure 5 Sensor Integration