

# Solar Powered Air Purification System

Bhagyashri Mangesh Patil<sup>1</sup>, Shivkumar Rajesh Jadhav<sup>2</sup>, Avdhut Shubhash Patil<sup>3</sup>,

Kiran Srirang Jadhav<sup>4</sup>, Harshal Vinod Sagare<sup>5</sup>, Ashish Kalaynrao Ningadale<sup>6</sup>

<sup>1,2,3,4,5</sup>Dept. of Electrical Engineering Shree Santakrupa Institute of Engineering and Technology,  
Ghogaon, Karad, India

**Abstract**—Air quality degradation has become one of the most pressing environmental concerns worldwide, driven by increasing urban growth, industrial expansion, and rising energy demands. Exposure to polluted air negatively affects public health and contributes to environmental deterioration. Most existing air purification technologies rely heavily on conventional electrical power sources, leading to higher energy consumption and additional environmental burdens. To address these challenges, this study proposes a solar-powered air purification system that combines renewable energy utilization with advanced air-cleaning technology.

The developed system harnesses solar energy through photovoltaic panels, which supply power to the purification unit and charge a battery storage system for continuous operation. An Arduino-based control module manages system functions and optimizes performance based on real-time conditions. Air quality is continuously monitored using gas and particulate matter sensors, allowing the system to automatically regulate airflow through a BLDC motor according to pollution levels.

For effective purification, the design incorporates a multi-stage filtration process consisting of HEPA and activated carbon filters. This arrangement efficiently captures fine particulate matter, harmful gases, volatile organic compounds (VOCs), and unpleasant odors. The system is capable of operating independently of the electrical grid, making it particularly suitable for densely populated urban areas, remote regions, and locations experiencing unstable power availability.

Experimental evaluation demonstrates that the proposed solution achieves effective air purification while maintaining low operating costs and reduced environmental impact. By integrating renewable energy generation with intelligent air quality management, the system offers a practical, sustainable, and economically viable approach to enhancing indoor and outdoor air quality. Furthermore, its modular design enables scalability for a wide range of applications, supporting broader adoption of clean energy technologies in environmental protection initiatives.

**Index Terms**— Solar energy, air pollution, air purifier, HEPA filter, activated carbon filter, renewable energy, Arduino, air quality monitoring.

## I. INTRODUCTION

With the continuous growth of cities, industrial activities, and population density, maintaining clean air has become a critical environmental and public health challenge. Air pollution is responsible for numerous health complications and negatively impacts ecosystems, climate, and overall living conditions. While conventional air purification systems can effectively remove contaminants from the air, they generally rely on grid-supplied electricity, resulting in increased energy consumption and a larger carbon footprint.

To address these concerns, the proposed Solar-Powered Air Purification System presents a sustainable and energy-efficient solution. The system utilizes solar energy as its primary power source, enabling air purification without placing additional demand on conventional energy resources. Through the integration of photovoltaic solar panels and modern filtration techniques, the system is designed to deliver clean and healthy air while minimizing environmental impact.

The purification process incorporates multiple treatment stages, including HEPA filtration, activated carbon adsorption, and UV-C sterilization. Together, these technologies effectively capture fine particulate matter, remove volatile organic compounds (VOCs), reduce allergens, eliminate unpleasant odors, and neutralize harmful bacteria and microorganisms present in the air. By operating on renewable energy, the system decreases dependence on fossil-fuel-based electricity, lowers operational costs, and supports environmentally responsible practices. In addition, its autonomous and energy-independent design makes it

suitable for a wide range of applications, including residential spaces, public areas, remote communities, disaster-relief operations, and regions where electricity supply is limited or inconsistent. As a result, the Solar-Powered Air Purification System offers a practical, cost-effective, and sustainable approach to improving air quality while promoting the adoption of clean energy technologies.

## II. LITERATURE REVIEW

### 1. Air Purification Technologies

Numerous studies have investigated the performance and efficiency of air purification technologies in reducing airborne contaminants. Research conducted by Nazaroff provides a comprehensive evaluation of different air-cleaning methods, highlighting their capabilities and limitations in removing pollutants from indoor environments. Such studies emphasize the importance of selecting appropriate purification techniques based on the nature and concentration of contaminants.

Understanding particulate matter is equally important for designing effective purification systems. Investigations by Araújo and colleagues focused on the measurement and characterization of airborne particulate matter, offering valuable insights into pollutant composition, distribution, and associated health risks. These findings support the development of filtration systems capable of targeting fine particles and improving air quality.

Advanced filter materials have also received significant attention. Ge et al. examined the adsorption properties of activated carbon for the removal of sulfur-containing pollutants commonly associated with smog formation. Their work demonstrated the effectiveness of activated carbon as a filtration medium for reducing harmful gaseous emissions and enhancing overall purification performance.

### 2. Integration of Solar Energy

The incorporation of renewable energy into environmental protection systems has become an important area of research. The publication *Basic Photovoltaic Principles and Methods* by the Solar Energy Research Institute (SERI) provides the theoretical foundation for photovoltaic energy conversion and serves as a key reference for solar-powered applications.

Several researchers have explored the application of solar energy in air purification systems. Kumar et al. presented the design and development of a solar-powered air purifier that combines renewable energy generation with air-cleaning technology. Their study demonstrated the feasibility of operating purification devices independently of conventional power sources. Further advancements were reported in studies focusing on activated carbon-based solar air purifiers, where renewable energy was effectively utilized to power filtration mechanisms while maintaining high pollutant removal efficiency. Additionally, Dhawale et al. (2023) introduced a solar-powered air purification model designed to operate efficiently under varying environmental conditions. Their findings highlighted the potential of solar-driven systems to provide sustainable, energy-efficient, and environmentally friendly solutions for improving air quality.

Overall, the existing literature indicates that combining advanced filtration technologies with solar energy can significantly enhance the sustainability and effectiveness of air purification systems. These studies provide a strong foundation for the development of the proposed Solar-Powered Air Purification System. indoor air purifier that includes an air quality monitor, similar to your proposed design.

**IoT and Intelligent Systems:** IoT Integration: Kousalya et al. (2022) and Choudhary et al. (2023) both researched IoT-based air purifiers, with the latter focusing on the use of HEPA filters.

**Intelligent Control:** Wang et al. (2020) focused on the design and research of intelligent air purifier systems, which aligns with your use of microcontrollers like Arduino to automate purification based on sensor data.

**Technological Gaps and Rationale:** Your paper should emphasize that while conventional air purifiers are effective, they are limited by their dependence on the electrical grid, which increases carbon emissions. The literature indicates a move toward:

**Energy Independence:** Creating systems that can operate in off-grid or remote locations.

**Sustainable Materials:** Integrating renewable energy simulation with sustainable materials.

**Real-Time Automation:** Moving from manual operation to sensor-driven, automated systems that respond to specific pollutant levels (e.g., activating when  $PM_{2.5} > 50 \mu\text{g}/\text{m}^3$ ).

III. METHODOLOGY

Schematic Diagram:

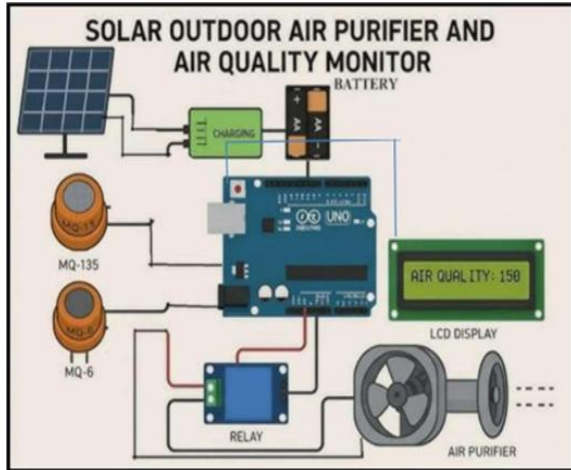


Fig. No. 1 Schematic Diagram

**Solar Panel:** Solar panels capture solar energy and convert it into electrical energy using photovoltaic (PV) cells, which are generally manufactured from semiconductor materials like silicon. When sunlight strikes these cells, electrons are released, producing direct current (DC) electricity. The generated DC power is typically supplied to an inverter, where it is converted into alternating current (AC) for use in electrical devices and household applications.

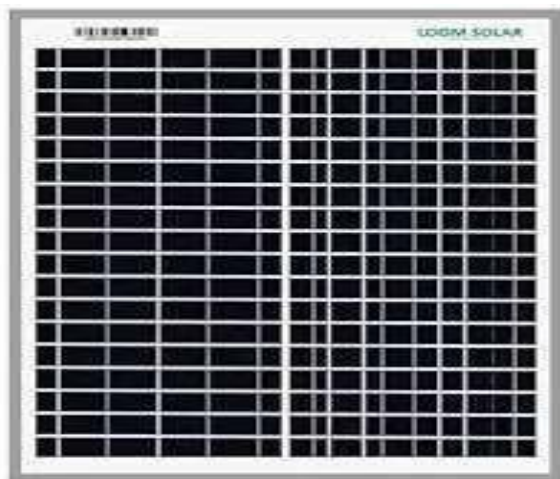


Fig No.2 Solar Panel

**Charge Controller:** A charge controller manages the transfer of electrical energy from the solar panel to the battery and connected devices. Its main function is to regulate charging conditions, prevent excessive

charging, and maintain safe voltage levels. By controlling the charging process, it helps improve battery lifespan and supports the efficient operation of the overall system.



Fig No. 3 Charge Controller:

**Battery:** Batteries are devices designed to store energy chemically and release it as electrical power when required. They consist of one or more electrochemical cells, each comprising an anode, cathode, and electrolyte. Through chemical reactions, these cells produce a flow of electrical current to power various electronic devices.



Fig No. 4 Battery

**Arduino:** Arduino is an open-source microcontroller platform that combines programmable hardware with easy-to-use software. It can process inputs from sensors, switches, or communication modules and generate corresponding outputs such as controlling LEDs, operating motors, or executing automated tasks. Due to its simplicity and versatility, Arduino is widely utilized in embedded systems, automation, and prototype development.



Fig No. 5 Arduino

**Sensor:** Sensors are essential for continuously tracking environmental conditions and providing real-time data. In this system, the MH-Z14A gas sensor is used to measure carbon dioxide (CO<sub>2</sub>) concentration through non-dispersive infrared (NDIR) technology. The sensor offers high accuracy, excellent selectivity, and a long service life while operating independently of oxygen levels, making it suitable for monitoring air quality and supporting automated system control.

**BLDC Motor:** A Brushless Direct Current (BLDC) motor is a modern electric motor that operates without brushes or mechanical commutators. Current switching is performed electronically, resulting in improved efficiency, lower maintenance requirements, and quieter operation. Compared to conventional brushed motors, BLDC motors provide enhanced reliability and smoother performance, making them ideal for air circulation applications.



Fig No. 6 BLDC Motor

**Display:** Liquid Crystal Displays (LCDs) are flat panel display technologies that rely on liquid crystals to produce visuals. These displays are commonly used in consumer electronics such as mobile phones, televisions, and

computer screens. Their compact design and energy efficiency make them ideal for a wide range of digital display applications.



Fig No. 7 Display

**Filter:** This project incorporates two types of air filters for effective air purification.

**HEPA Filter:** High-Efficiency Particulate Air (HEPA) filters are capable of removing up to 99.97% of airborne particles with a size of 0.3 microns or larger. They consist of a dense network of fine glass or synthetic fibers that capture contaminants such as dust, pollen, mold spores, and bacteria through filtration mechanisms including diffusion, interception, and impaction.

HEPA filters play a vital role in enhancing indoor air quality and are particularly useful for people affected by allergies or respiratory conditions.

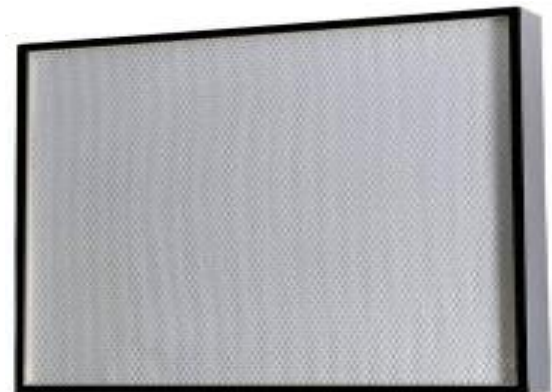


Fig No. 8 HEPA Filter

**Active Carbon Filter:** Active carbon filters employ porous carbon materials to purify air or liquids through adsorption, a process where impurities chemically adhere to the surface of the carbon. These filters are highly effective at removing Odors, chlorine, volatile organic compounds (VOCs), and certain pesticides, thereby enhancing air quality and taste, though they do not eliminate dissolved minerals.

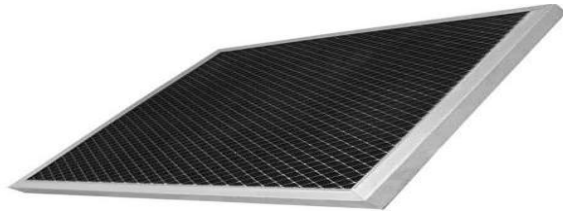


Fig No. 9 Active Carbon Filter

**Thyristor:** Thyristors in Power Electronics are used as power semiconductor devices which are used as on/off switches in power control circuits. A power semiconductor device is a

A thyristor is a semiconductor device used primarily as a switch or rectifier in power electronic systems such as switch-mode power supplies. It is one of the most important power semiconductor devices and is widely used in various electronic circuits. Thyristors function as bi-stable switches, operating between non-conducting and conducting states.

#### IV. GENERALIZED METHODOLOGY

The development and implementation of a solar-powered air purification system generally follow four main stages: design, assembly, operation, and evaluation. This structured approach focuses on energy efficiency and effective pollutant removal.

##### 1. Design Phase

**Energy Assessment:** Solar irradiance at the installation site is evaluated to determine the appropriate sizing of photovoltaic (PV) panels, typically ranging from 100–500 W for small-scale systems. Tools such as PV Watts or simulation software are used to estimate daily energy production.

**Filtration Selection:** Filters are selected based on the target pollutants. HEPA filters are used to capture 99.97% of particles as small as 0.3 microns, while activated carbon is used to adsorb volatile organic compounds (VOCs). Advanced systems may also include photocatalytic oxidation (PCO) using materials such as TiO<sub>2</sub>, which activates under UV light to degrade pollutants.

**System Integration:** Airflow is optimized using Computational Fluid Dynamics (CFD) simulations to enhance efficiency in fan speed and filter placement. Typical airflow rates range from 100–300 CFM. Sustainability is also considered by incorporating recyclable materials and reducing energy losses through components such as MPPT charge controllers.

##### 2. Assembly Phase

**Solar Power Setup:** Photovoltaic panels are installed at an optimal tilt angle (approximately 30–45° facing south in the Northern Hemisphere). They are connected to a charge controller, battery storage, and inverter.

**Filtration Assembly:** The filtration system is arranged in layers, including a pre-filter, HEPA filter, activated carbon filter, and optionally a UV or PCO stage. A blower fan powered by the solar energy system is integrated to ensure airflow.

**Control System:** A microcontroller is used to automate system operation, such as activating the fan when air quality sensors detect high pollution levels (e.g., PM<sub>2.5</sub> above 50 µg/m<sup>3</sup>).

**Testing:** The assembled system is tested for electrical safety, airflow performance, and preliminary purification efficiency using smoke or aerosol-based testing methods.

##### 3. Operation Phase

**Energy Harvesting:** During daylight hours, solar panels generate electricity, which is used to charge the battery and power the system. Any surplus energy supports direct operation.

**Air Intake and Purification:** Air is drawn into the system using fans or natural convection in chimney-based designs, where solar heating enhances upward airflow.

**Stage 1: Pre-Filtration:** The first stage removes larger particles such as dust and pollen before further filtration stages. **Stage 2: Fine Filtration:** The HEPA filter removes fine particulate matter, while the activated carbon layer adsorbs harmful gases.

**Stage 3: Advanced Treatment:** UV or photocatalytic oxidation (PCO) is used to eliminate bacteria, viruses, and remaining volatile organic compounds (VOCs), after which clean air is released to improve surrounding air quality.

**Monitoring and Feedback:** Sensors continuously measure parameters such as air quality index (AQI), temperature, and humidity. The collected data can be stored or accessed remotely through applications for monitoring purposes.

**Passive vs. Active Modes:** During low sunlight conditions, the system operates on battery power or switches to a passive mode to reduce energy consumption.

#### 4. Evaluation Phase

**Performance Metrics:** System efficiency is evaluated using parameters such as Clean Air Delivery Rate (CADR), energy consumption per unit volume (kWh/m<sup>3</sup>), and pollutant reduction efficiency (e.g., up to 90% PM removal during testing).

**Field Testing:** The system is tested in real-world environments such as urban locations, and air quality measurements are compared before and after purification using appropriate measuring instruments.

**Optimization:** Collected data is analyzed to improve system performance by adjusting parameters such as fan speed for better energy efficiency or upgrading filters for targeted pollutants.

### V. VARIATIONS IN METHODOLOGY

**Passive Systems:** These rely on solar chimney effects to generate natural airflow and are suitable for large-scale outdoor applications with minimal mechanical components.

**Hybrid Systems:** These combine solar power with thermoelectric generation to enhance energy harvesting using temperature differences during operation.

**Portable Units:** Common in student or prototype projects, these systems often use 3D-printed enclosures and Arduino-based control systems, typically costing under \$200.

**Outdoor Applications:** Designed for public environments, these systems prioritize high-capacity filtration and durability, operating entirely on solar energy to reduce urban air pollution.

### VI. CONCLUSION

The solar-powered air purification system integrates renewable energy with multi-stage filtration technology to provide a sustainable and efficient solution for improving air quality pollution. By addressing the technological gaps of conventional grid-dependent purifiers, this project offers a portable, autonomous, and energy-independent alternative that significantly improves public health and environmental quality.

### ACKNOWLEDGEMENT

The authors would like to express their sincere

gratitude to Mrs. B. M. Patil, Project Guide, and Mr. S. H. Mali, Head of the Electrical Engineering Department, for their invaluable guidance, technical insights, and constant encouragement throughout this project. We also extend our thanks to Dr. S. B. Kulkarni, Principal of Shree Santkrupa Institute of Engineering & Technology (SSIET), Ghogaon, for providing the necessary institutional facilities and a conducive environment for our research. Furthermore, we are grateful to Dr. Babasaheb Ambedkar Technological University, Lonere, for the academic framework that made this work possible. Finally, we would like to thank our families and peers for their continuous support during the design, assembly, and testing phases of this solar-powered system.

### REFERENCES

- [1] Y. K. Cho, S. Alaskar, and T. A. Bode, "BIM-integrated sustainable material and renewable energy simulation," in *Proc. Construction Research Congress 2010: Innovation for Reshaping Construction Practice*, J. Ruwanpura, Y. Mohamed, and S. Lee, Eds. Banff, AB, Canada: American Society of Civil Engineers, 2010, pp. 288–297.
- [2] London Councils, *The Control of Dust and Emissions from Construction and Demolition—Best Practice Guidance*. London, U.K.: London Councils, 2006.
- [3] P. S. Araújo, D. B. Costa, and R. J. B. de Moraes, "Identification and characterisation of particulate matter concentration in construction jobsites," *Sustainability*, vol. 6, pp. 7666–7688, 2014, doi: 10.3390/su6117666.
- [4] D. B. Costa and R. J. B. de Moraes, "Identification and characterisation of particulate matter concentration in construction jobsites," *Sustainability*, vol. 6, pp. 7666–7688, 2014, doi: 10.3390/su6117666.
- [5] W. W. Nazaroff, "Effectiveness of air cleaning technologies," in *Proc. 6th Int. Conf. Healthy Buildings*, Helsinki, Finland, 2000, vol. 2, pp. 49–54.
- [6] Solar Energy Research Institute (SERI), *Basic Photovoltaic Principles and Methods*, SERI/SP-290-1448, Solar Information Module 6213, 1982.
- [7] S. Ge, Z. Liu, Y. Furuta, and W. Peng,

- “Characteristics of activated carbon for removal of sulphur particles,” [Incomplete publication details].
- [8] D. Ardmar and J. Bodin, *Design of an Air Purifier*. [Incomplete publication details].
- [9] M. Kumar, S. J. Singh, P. K. Shukla, and R. V. Singha, “Design and fabrication of solar powered air purifier,” *International Research Journal of Engineering and Technology (IRJET)*, vol. 5, no. 4, Apr. 2018.
- [10] Y. Wang, W. Wang, Z. Zhang, P. Zhou, and H. Jiang, “Design and research of intelligent air purifier system,” in *Proc. IEEE Int. Conf. Mechatronics and Automation (ICMA)*, Beijing, China, 2020, pp. 1822–1826.
- [11] R. P. Eldho, C. P. Raga Sudha, D. Rani, A. P. Tiwari, M. Ashraf, and Akanksha, “Design and development of activated carbon-based solar air purifier,” in *Proc. 2022 IEEE 4th Int. Conf. Cybernetics, Cognition and Machine Learning Applications (ICCCMLA)*, Goa, India, 2022, pp. 250–255.
- [12] Dhawale, A. Kamble, S. Ghule, and M. Gawande, “Solar powered indoor air purifier with air quality monitor,” in *Proc. 2023 9th Int. Conf. Electrical Energy Systems (ICEES)*, Chennai, India, 2023, pp. 206–209.
- [13] G. Kousalya *et al.*, “Design of IoT based indoor air purifier,” in *Proc. 2022 Third Int. Conf. Intelligent Computing, Instrumentation and Control (ICICIC)*, 2022.
- [14] Y. Wang, W. Wang, Z. Zhang, P. Zhou, and H. Jiang, “Design and research of intelligent air purifier system,” in *Proc. IEEE Int. Conf. Mechatronics and Automation (ICMA)*, Beijing, China, 2020, pp. 1822–1826.
- [15] Choudhary, L. Saini, A. Ahmad, H. Banerjee, and F. Gazi, “Design and fabrication of an IoT based air purifier using HEPA filter,” in *Proc. 2023 11th Int. Conf. Internet of Everything, Microwave Engineering, Communication and Networks (IEMECON)*, Jaipur, India, 2023, pp. 1–6.