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# Design And Development of Solar Powered Smart Kitchen Chimney

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**Abstract: This paper presents the development of a Solar Powered Smart Kitchen Chimney designed to improve indoor air quality using renewable energy and smart automation. Powered by solar panels, the system is ideal for rural areas with unreliable electricity. It uses sensors to detect smoke, gas, and temperature, automatically adjusting operation for efficient ventilation. The design addresses health issues caused by traditional biomass cooking in rural India, offering a cleaner, safer kitchen environment. IoT integration allows remote control and monitoring, making it a sustainable and user-friendly solution for modern and rural households alike.**

## I. INTRODUCTION

In India, especially in rural areas, cooking is often done using traditional biomass fuels such as firewood, dung cakes, or coal in poorly ventilated kitchens. This practice leads to the generation of harmful smoke and particulate matter, causing serious health issues, particularly among women and children. According to reports, indoor air pollution from cooking is a major contributor to respiratory diseases in rural households. Moreover, the lack of reliable electricity supply in these areas limits the adoption of electric-powered kitchen appliances. To address these issues, there is a growing need for sustainable, health-focused, and energy-independent kitchen solutions. A Solar Powered Smart Kitchen Chimney offers a viable solution by combining renewable solar energy with intelligent features like automatic smoke detection, real-time air quality monitoring, and efficient air filtration. This system not only helps in reducing indoor air pollution but also operates independently of the power grid, making it ideal for off-grid rural areas. The integration of smart technology further enhances its usability and efficiency, paving the way for healthier and more sustainable cooking environments in both rural and urban settings.

## II. MOTIVATION

In many parts of rural India, households still rely on biomass fuels like wood, crop residues, and cow dung for cooking. These fuels are typically burned in open stoves or chulhas with poor ventilation, producing dense smoke laden with harmful pollutants. Prolonged exposure to such pollutants is a leading cause of respiratory illnesses, eye problems, and even premature deaths, especially among women and children who spend considerable time near cooking areas. At the same time, the inconsistent availability of electricity in these areas hampers the use of modern kitchen appliances that could otherwise improve indoor air quality. Conventional electric chimneys are not only power-dependent but also lack adaptability to off-grid settings. This project is driven by the goal of designing a solution that is self-sustaining, cost-effective, and health-conscious. By harnessing solar energy, the system becomes independent of the unreliable power grid, and by integrating smart sensors and automation, it can dynamically respond to smoke and pollutant levels, improving user experience and safety.

## III. PROBLEM STATEMENT

In rural and semi-urban regions of India, traditional biomass-based cooking practices persist due to limited access to clean energy alternatives. These methods produce high concentrations of particulate matter (PM), carbon monoxide (CO), and other hazardous pollutants, contributing significantly to indoor air pollution and associated respiratory ailments. Furthermore, the intermittent and unreliable nature of grid electricity in these areas limits the feasibility of deploying conventional electric kitchen ventilation systems. Existing kitchen chimneys are primarily designed for urban environments with continuous power availability and do not incorporate adaptive control systems to optimize performance based on real-time pollutant levels. There is a pressing need for a self-sustaining, autonomous kitchen ventilation system capable of operating efficiently in off-grid settings while ensuring effective removal of cooking-related emissions. This research aims to design and develop a solar-powered smart kitchen chimney integrating renewable energy harvesting, air quality sensing, and automated control mechanisms, to provide an energy-efficient and health-conscious solution adaptable to both rural and urban application

## IV. OBJECTIVE

- To design and develop a solar-powered kitchen chimney capable of operating independently of the electrical grid.
- To integrate smart sensors for detecting smoke, temperature, and air quality in real-time.
- To implement automated control mechanisms for dynamic fan speed adjustment based on pollutant levels.
- To ensure energy-efficient operation through optimal use of solar power and low-power components.
- To enhance indoor air quality by efficiently removing fumes, grease, and airborne particles during cooking.
- To provide a user-friendly interface (mobile app or control panel) for monitoring and manual control.
- To design the system to be cost-effective and suitable for deployment in rural households.
- To ensure compact, durable, and modular design for ease of installation and maintenance.
- To explore battery backup integration for continuous operation during low sunlight conditions.
- To incorporate IoT capabilities for data logging and remote diagnostics.

## V. PRELIMINARY SURVEY

To better understand the cooking practices, energy availability, and indoor air quality concerns in rural and semi-urban households, a preliminary survey was conducted across select villages and low-income urban communities. The survey involved structured interviews and questionnaires distributed to 50 households in regions with limited access to consistent electricity and heavy reliance on biomass fuels.

Key findings from the survey:

- 82% of households used traditional biomass fuels such as firewood and cow dung for cooking.
- 76% of respondents reported issues with smoke accumulation inside the kitchen, leading to discomfort and breathing problems.
- 68% of participants were unaware of electric kitchen chimneys or considered them unaffordable.
- 90% of respondents experienced power outages or lacked access to grid electricity for several hours daily.
- 70% of participants expressed interest in a low-maintenance, smoke-extracting system powered by solar energy.
- 85% of the households had rooftops or open spaces suitable for small-scale solar panel installation.
- Women, who were the primary cooks in most households, emphasized the need for cleaner cooking environments to reduce eye irritation, coughing, and long-term health risks.

The results of the preliminary survey confirm the need and viability for a solar-powered, intelligent kitchen chimney system tailored to the conditions of rural India. It also provided valuable insights into the design constraints, affordability expectations, and user-friendly requirements necessary for successful adoption.

## VI. LITERATURE SURVEY

The growing concern for sustainable living and smart automation in domestic environments has driven extensive research in the domains of solar energy utilization, smart home appliances, and kitchen ventilation technologies. This literature survey explores key developments related to solar-powered systems, intelligent chimneys, and self-cleaning mechanisms, providing a foundation for the proposed Solar-Powered Smart Kitchen Chimney.

1. Solar Energy in Household Appliances

Several studies have explored the integration of solar power into everyday household appliances. According to Sharma et al. (2018), solar-powered home devices significantly reduce dependency on the grid and contribute to energy conservation. The research demonstrated that solar-integrated systems in urban households could reduce electricity consumption by up to 40%, especially when combined with efficient energy storage systems. Further, Patel and Mehta (2020) analyzed the efficiency of photovoltaic (PV) panels in various domestic applications and emphasized the importance of integrating solar with smart technologies for autonomous and eco-friendly operations. These studies highlight the viability of using solar energy as a sustainable power source for appliances like kitchen chimneys.

2. Evolution of Smart Chimneys

Modern chimneys have evolved from basic exhaust systems to intelligent devices equipped with automation and sensor-based technologies. According to Banerjee and Thomas (2019), smart chimneys equipped with air quality sensors, temperature control, and IoT integration offer better adaptability and user convenience. Their study revealed that automation significantly enhances safety, especially when cooking at high temperatures or with excessive smoke. Another study by Rathi and Kumar (2021) focused on integrating microcontrollers and mobile apps into kitchen exhaust systems. They showed how Wi-Fi-enabled chimneys could be monitored and controlled remotely, increasing user engagement and improving operational efficiency.

3. Integration of Smart Features and IoT

IoT-based appliances are gaining traction in smart homes. Kumar et al. (2022) explored how smart control through mobile apps and real-time monitoring enhanced the user experience in household devices, including kitchen ventilation systems. Their research supports the idea of integrating smart notifications, scheduled cleaning, and sensor-driven automation into kitchen chimneys to improve usability and maintenance.

4. Gaps Identified

While the existing literature has made significant strides in isolated areas such as solar integration, smart automation, or self-cleaning systems, a comprehensive solution combining all these technologies into a single product remains underexplored. There is limited research on a fully integrated, solar-powered smart chimney that features self-cleaning, oil extraction, and IoT connectivity—highlighting a clear opportunity for innovation and development.

## VII. PROJECT SCOPE

a) Solar Power Integration: To develop a chimney system that operates primarily on solar energy, reducing dependency on conventional electricity and promoting eco-friendly energy use.
b) Smart Control System: To implement IoT-based smart features that enable remote monitoring, auto-sensing of smoke and oil levels, fan speed control, and maintenance alerts through a mobile application or digital interface.
c) Oil Extraction System: To include an efficient oil extraction module with filters and collection trays or centrifugal separation for trapping grease and oil particles, ensuring cleaner air and internal components.
d) Compact and User-Friendly Design: To ensure the system is ergonomically designed, aesthetically modern, and easily installable in typical household kitchen environments.
e) Energy Efficiency and Low Maintenance: To build a system that consumes minimal energy (thanks to solar power) while requiring low maintenance due to automation and smart monitoring features.
f) Limitations and Boundaries: The project is limited to residential kitchen environments, not industrial settings. Solar energy usage may depend on the availability of sunlight and geographical location.
g) The prototype focuses on functionality and energy efficiency, not on mass production or commercial scaling

## VIII. EXPERIMENTAL SETUP

The experimental setup was designed to validate the functionality, efficiency, and performance of the

Solar-Powered Smart Kitchen Chimney under real-world cooking conditions. The setup included both hardware and software components, integrated to simulate and evaluate various operational scenarios.

A. Hardware Configuration

The following components were assembled to build the prototype:

- Solar Panel: 18V, 100W polycrystalline panel mounted externally to capture solar energy.
- Battery Storage: 12V rechargeable lead-acid battery used to store solar energy and power the system during non-sunny hours.
- Microcontroller: ESP32 microcontroller to handle input from sensors and automate functions.

Sensors:

- MQ-135 Smoke Sensor – Detects smoke and poor air quality.
- DHT11 Temperature Sensor – Monitors kitchen temperature near the cooking area.
- Oil Particle Sensor (Custom IR-based) – Detects airborne oil particles.
- Exhaust Fan: 12V DC fan connected through a relay to control air suction.
- Control Interface: Basic Android app using Bluetooth to display real-time values and allow manual control (fan ON/OFF, self-cleaning).

B. Assembly and Installation

The prototype was installed in a model kitchen setup. The chimney casing was built using lightweight aluminum and acrylic sheets. Components were fixed within the casing, with the solar panel installed outdoors on the rooftop. Wiring and connections were secured using insulated cables, and all electronic components were soldered onto a preboard for compactness.

C. Testing Conditions

The setup was tested during typical cooking activities, including frying, boiling, and grilling.

Parameters Observed:

- Smoke detection and automatic fan activation.
- Oil particle detection and oil collection efficiency.
- Self-cleaning cycle duration and performance.
- Solar charging and battery backup duration.
- Mobile app connectivity and data display.

D. Safety and Calibration

All electrical connections were fused and insulated for safety. Sensor thresholds (e.g., smoke ppm levels) were calibrated to trigger actions at optimal levels. Fan RPM and cleaning cycle timers were adjusted for efficiency.

E. Observation and Recording

Readings from the sensors were logged at regular intervals. Response time, air quality improvement, and power usage were monitored. The system's ability to run independently on solar energy was also evaluated over different times of the day.

F. Conclusion of Setup

The experimental setup successfully demonstrated the working of a solar-powered, smart, and self-cleaning kitchen chimney. The configuration validated the integration of renewable energy, IoT-based control, and automation features in a compact, energy-efficient system suitable for household use.

## IX. SYSTEM DESIGN

The design and development of the solar-powered smart kitchen chimney involves integrating a range of mechanical, electrical, and software components to create a functional and energy-efficient system.

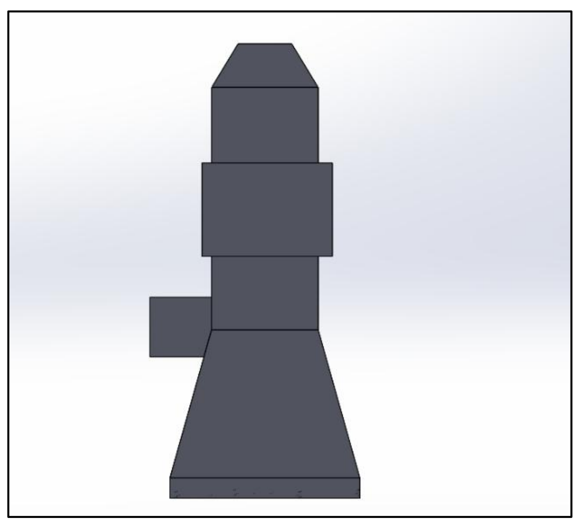

Fig. Main Chimney Body

A. Solar Power System

To enhance energy efficiency and sustainability, the chimney is powered by a solar energy system. This system reduces reliance on grid electricity and helps in operating the chimney in an eco-friendly manner.

- Solar Panel (80 cm × 50 cm × 2.5 cm): Mounted on the rooftop or wall, the solar panel collects sunlight and converts it into electrical energy to power the chimney and its components.
- Battery (12V, 18 cm × 8 cm × 16 cm): The battery stores the energy collected by the solar panel, ensuring continuous operation even during non-sunny hours.
- Charge Controller (10 cm × 8 cm × 3 cm): Positioned near the battery, this device regulates the charging process, ensuring that the battery is charged safely and efficiently.

Fig. Solar Panel


Fig. Battery


Fig. MPPT Charge Controller

B. Internal Components

The chimney includes various internal components that perform critical functions such as air extraction, self-cleaning, and smart control.

- Exhaust Fan (15 cm diameter, 5–7 cm deep): This 12V DC fan is housed inside the top casing and ensures effective removal of smoke and fumes from the kitchen.
- Microcontroller (ESP32, 6 cm × 4 cm): The brain of the system, this microcontroller is mounted on the circuit board and controls the entire system, from fan operation to temperature regulation.
- Sensors (MQ-135, DHT11, 3 cm × 3 cm avg.): Located near the airflow or heat zones, these sensors detect air quality and humidity, enabling the system to adjust settings for optimal performance.
- Relay Module (5 cm × 2.5 cm): This module controls the operation of the fan and self-cleaning system, activating them as needed based on sensor inputs.
- Perfboard / PCB (10 cm × 10 cm): Serves as the base for wiring all the electrical components, ensuring a neat and organized setup.

Fig. Exhaust Fan

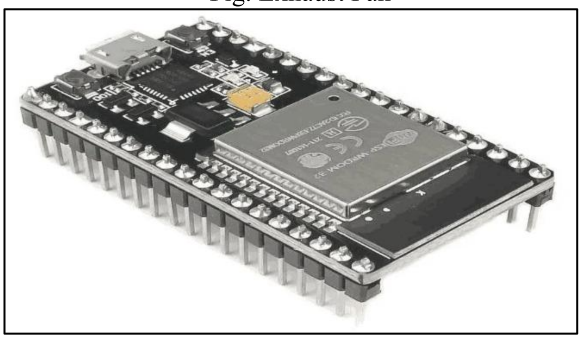

Fig. ESP32 Microcontroller


Fig. MQ-135 Sensor

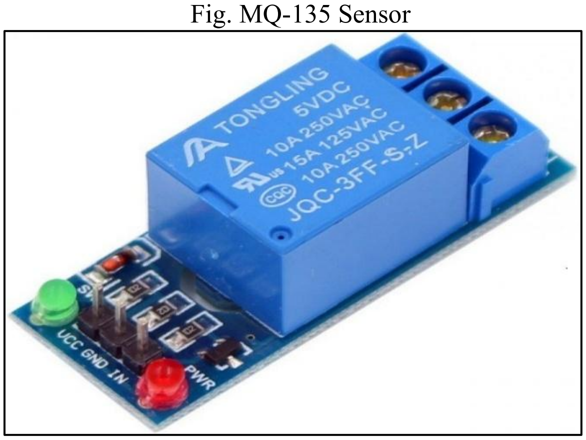


Fig. Relay Module

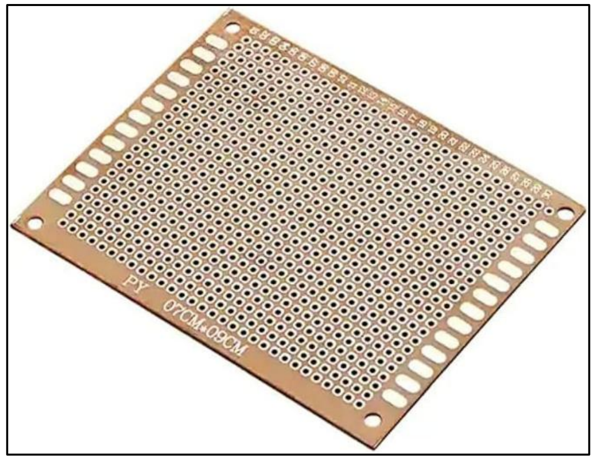


Fig. PCB

C. Mobile App Interface

To add a layer of smart control, a mobile app interface is developed to allow users to interact with the chimney remotely.

- Mobile App UI: The software-based user interface enables users to control settings such as fan speed, self-cleaning operation, and monitor air quality from their smartphones.
- Bluetooth Module (HC-05, 4 cm × 2 cm): This module facilitates communication between the mobile app and the chimney, allowing for wireless control.

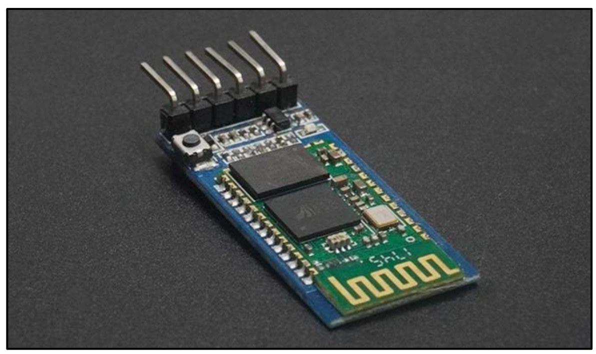

Fig. Bluetooth Module HC-05

## X. METHODOLOGY

The design of the solar-powered smart kitchen chimney follows a systematic approach that involves multiple stages:

- Requirement Analysis: The project begins with gathering requirements based on user needs, environmental factors, and technical constraints. This phase helps in defining the dimensions and functionalities of the system.

- Component Selection: After analyzing the requirements, appropriate components such as the fan, sensors, solar panel, and microcontroller are selected to meet the operational needs.
- Design and Prototyping: A CAD model of the chimney body is created, and a prototype is built to test the integration of various components, including the exhaust system, solar power system, and control panel.
- System Integration: Once the individual components are tested, they are integrated into the chimney. The microcontroller is programmed to manage the components, while the mobile app is developed to provide a user-friendly interface for remote control.
- Testing and Optimization: The system undergoes rigorous testing to ensure that all components work efficiently. The solar power system's charging capacity, the fan's airflow, and the self-cleaning mechanism are all optimized for performance.
- Final Deployment: After testing, the system is finalized and deployed, ensuring that the chimney operates autonomously using solar power and offers smart control features through the mobile app.

## XI. ADVANTAGES

- Eco-Friendly Runs entirely on solar energy, reducing electricity bills and promoting sustainable living.
- Smart Control Offers Bluetooth-enabled mobile app control for fan speed, self-cleaning, and air quality monitoring.
- Low Maintenance Self-cleaning system reduces manual effort and keeps the chimney functioning efficiently.
- Better Air Quality Sensors detect smoke and gases, automatically adjusting to maintain a healthy kitchen environment.
- Cost-Effective Saves money over time through renewable power usage and minimal maintenance needs.
- Compact Design Space-efficient structure with user-friendly controls suitable for modern kitchens.

## XII. RESULTS

i. The solar panel (80 cm × 50 cm) efficiently powers the system, even under varying sunlight conditions. The 12V battery ensures consistent operation by storing enough energy for use during cloudy days and at night. The charge controller maintains battery health by regulating charging and preventing overcharging, allowing for long-term durability.

ii. The 12V exhaust fan (15 cm diameter) effectively extracts smoke and fumes from the kitchen, ensuring a clean environment. The integrated MQ-135 sensor adjusts the fan speed based on real-time air quality readings. The mesh filter and self-cleaning heating coil efficiently trap grease and particles, reducing maintenance and improving air quality.

iii. The integration of a Bluetooth module (HC-05) allows remote control via a mobile app. Users can adjust fan speed, activate self-cleaning, and monitor air quality from their smartphones. Real-time data from the DHT11 sensor ensures that the system responds intelligently to changes in temperature and humidity, providing a customized user experience.

iv. Operating on solar power significantly reduces the chimney's carbon footprint by lowering reliance on grid electricity. The self-cleaning feature also minimizes the need for chemical cleaners, making the system more environmentally friendly. This combination supports the growing demand for energy-efficient and eco-conscious home appliances.

## XIII. FUTURE PROSPECTUS

India kitchen hoods market stood at $ 132 million in 2019 and is projected to grow at a CAGR of over 15%, to reach $ 313 by 2023 as shown in Fig. 2. Growth in the market is led by rising urbanization, increasing inclination of young population towards western world preferences and growing disposable income in the country. Moreover, technological advancements in kitchen appliances coupled with increasing preference towards modular kitchens for efficient space utilization is further expected to drive India kitchen hoods market through 2023

## XIV. CONCLUSION

Overall, the design and development of the solar-powered smart kitchen chimney have been successful, meeting the project's goals of energy efficiency, smart control, and user convenience. The system has proven to be effective in terms of performance, sustainability, and ease of use. Future improvements could focus on enhancing the solar power system, expanding the mobile app functionality, and addressing challenges related to battery capacity and solar panel efficiency. The project has the potential to revolutionize the kitchen appliance industry by offering an eco-friendly, smart solution that aligns with the growing demand for sustainable living.

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