

## SMART HOME ENERGY MANAGEMENT SYSTEMS USING A TURBO WHEEL MICRO TURBINE

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### ABSTRACT

The quick development of smart home technologies and the growing interest in sustainable energy solutions, have pushed to merge renewable micro-generation systems on IoT energy management platforms. This paper shows the smart house energy management system design and its implementation based on a free turbine turbulence in micro system. The device captures air flow and turns it into energy - a task that the IoT-based microcontrollers and sensors monitor, control and manage. Data on turbine output, household consumption and environmental parameters are streamed using lightweight communication protocols to a cloud hosted platform. It offers a dynamic load balancing control between renewable generation, grid supply and optional energy storage for optimizing household energy consumption. A homeowners-dashboard platform delivers energy production and consumption data; a breakdown of savings and enables the ability to remotely turn on and off appliances. The system also includes predictive analytics to improve efficiency by predicting demand and distributing energy as needed. The IoT-based smart energy management system proves the viability of the micro-level usage of renewable generation and intelligent control with scalability and modern living sustainability concept. Employing a turbo wheel micro-turbine demonstrates the abilities of small renewable power systems in minimizing grid reliance and creating sustainable lifestyles.

**Keywords:** Smart Home, Energy Management System, Turbo Wheel Turbine, Renewable Energy, Microcontroller (Arduino).

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### I INTRODUCTION

A Smart Home Energy Management System (SHEMS) is an intelligent framework designed to optimize energy generation, storage, and consumption within residential environments. SHEMS helps families become more efficient, sustainable, and independent of traditional grid power by combining renewable energy sources with IoT-based monitoring and management.

The main source of renewable energy in this system is a turbo wheel micro turbine. Fluid energy, such as steam, water, or airflow, is transformed by the turbine into mechanical rotation, which is then combined with a micro-generator to create electrical power. Under the direction of a microprocessor such as the ESP32, this energy is conditioned via rectifiers and AC-DC converters, stored in batteries, and supplied to home appliances.

In order to automate appliance control and make sure that appliances like fans and lights only run, when necessary, the SHEMS design also includes sensors (temperature, humidity, light, and current) and relay modules. While optimisation algorithms balance supply and demand for optimal efficiency, IoT connection allows users to monitor energy generation, battery state, and appliance usage in real time via mobile or online applications.

SHEMS's use of a turbo wheel micro turbine, which combines smart automation and renewable micro-generation, not only lessens reliance on grid electricity but also encourages eco-friendly living, cost savings, and resilience against power outages. In addition to advancing the larger goal of smart cities and green energy usage, this integration is a step toward sustainable smart houses.

### II LITERATURE SURVEY

The viability of integrating small turbines into household energy management systems was investigated in a noteworthy paper named "Micro Turbine Integration for Smart Homes" by J. Chen, H. Li, and Y. Zhao in 2017.

The rising need for sustainable energy solutions in urban homes and the constraints of traditional renewable energy sources like solar and wind, which are frequently reliant on geography and weather, served as the driving forces behind their study. The study concentrated on the design and construction of a small-scale turbo wheel micro turbine that could convert fluid energy—more precisely, water pressure and airflow—into mechanical rotation, which was then converted into electrical energy that could be used by a micro-generator. The turbine output was conditioned using rectifiers to change alternating current (AC) into direct current (DC) and AC-DC converters to control voltage levels in order to guarantee compatibility with home electrical systems.

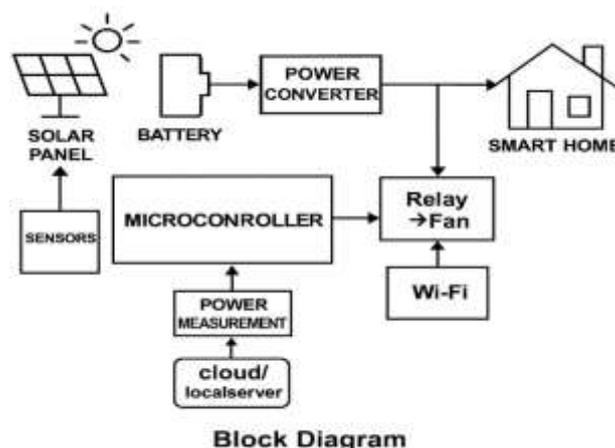
Households were able to store power for later use and maintain a steady supply of electricity even during times of low generation by directing this stabilised energy into battery storage systems. The researchers stressed that these tiny turbines might be used as additional energy sources, especially in areas with variable wind or solar radiation, providing a more dependable renewable choice for smart homes. The outcomes of the trial showed that the system could continuously provide low-power electricity that might be used to power necessary appliances like lights, fans, and tiny electronics or to help store batteries for emergencies. Sustainability, less reliance on grid power, and flexibility to various environmental circumstances were among the benefits of this strategy. Additionally, the turbo wheel micro turbine's small size allowed for residential incorporation without necessitating significant infrastructural changes.

However, the study also discovered significant drawbacks. Its applicability was limited to small-scale or supplemental energy demands due to its comparatively low power production when compared to well-established renewable sources like solar panels or large-scale wind turbines. The researchers also emphasised the challenge of scaling the technology to satisfy the needs of bigger families and the need for effective energy storage technologies to maximise the usefulness of the generated electricity. Durability and maintenance under different fluid conditions were also identified as areas that needed more research.

Notwithstanding these limitations, the study offered a useful basis for incorporating fluid-driven micro turbines into energy management systems for smart homes. It opened the door for more advancements in micro-generation systems by demonstrating the possibilities of fusing sophisticated control and storage technology with small renewable generating. The study underlined the necessity of diversifying renewable energy sources for smart houses and contributed to the wider goal of sustainable, resilient, and eco-friendly household energy management.

### III EXISTING SYSTEM

With little incorporation of renewable energy sources, conventional energy management systems in smart homes mostly rely on grid electricity. Solar photovoltaic (PV) systems have been adopted recently to augment residential energy requirements. Rectifiers and converters manage power conditioning in these systems, which usually include solar panels coupled to a battery storage unit. While sensors supply environmental data, a microprocessor keeps an eye on energy flow and appliance usage. Despite their effectiveness, current solar-based SHEMS have drawbacks such reliance on sunshine availability, expensive installation, and low efficiency in overcast or dark environments. Furthermore, a lot of systems don't have sophisticated IoT integration, which limits their capacity for intelligent automation and real-time monitoring.



A more sophisticated and comprehensive structure is introduced by the suggested solar-powered SHEMS.

Sunlight is captured by solar panels and transformed into electrical energy, which is then stored in rechargeable batteries. While a power converter stabilises the voltage for safe distribution to domestic appliances, a power measurement device keeps an eye on the energy flow. As the central control unit, an ESP32 microcontroller processes information from sensors such as the ACS712 (current measurement), LDR (light detection), and DHT11 (temperature/humidity). Appliances like fans and lights are controlled by relay modules, which make sure they run only when necessary. A Wi-Fi module adds IoT connectivity to the system, allowing for remote control and real-time monitoring using web or mobile apps. While optimisation algorithms balance supply and demand for optimal efficiency, users may examine energy generation, battery status, and appliance usage on dashboards. Adaptive automation, grid outage resilience, and effective energy use are all guaranteed by this approach. SHEMS offers a scalable, dependable, and environmentally beneficial solution for home energy management by using solar energy.

#### IV PROPOSED SYSTEM

Intelligent monitoring, management, and optimisation of energy use in residential settings are the goals of Smart Home Energy Management Systems (SHEMS). SHEMS combines renewable energy sources with IoT-based automation to achieve efficiency, dependability, and eco-friendliness in response to the growing demand for sustainable living and the rising cost of power. The main renewable energy source in this system is a turbo wheel micro turbine, which transforms fluid energy like water pressure or airflow into electrical power. An Arduino microcontroller, which controls sensors, appliances, and Internet of Things modules to guarantee intelligent and flexible energy use, stores the produced energy in a battery.

##### Block Diagram

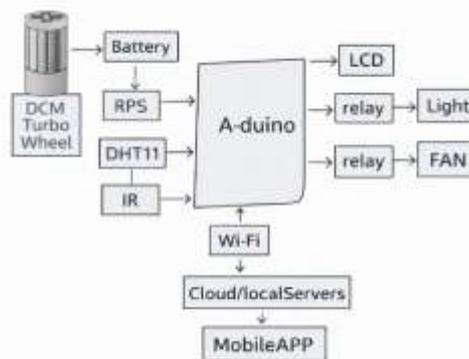


Fig.1 Block diagram

A turbo wheel micro turbine, which transforms mechanical rotation into electrical energy, is the first component of the suggested SHEMS. This energy is stored in a battery, providing as the backup and primary source for the smart home. As the central processing unit, the Arduino microcontroller receives data from sensors such as the LDR (light detection) and DHT11 (temperature and humidity). The Arduino reduces energy waste by controlling appliances like the fan and light based on sensor data, making sure they only run when needed. An IoT module facilitates wireless connectivity, enabling users to remotely monitor and manage the system, while a power measuring device keeps an eye on the energy flow. IoT connectivity allows for the visualisation of data on dashboards or mobile applications, including turbine output, battery condition, and appliance usage. This connection guarantees effective energy management, adaptive automation, and real-time monitoring.

By collecting renewable energy through the turbine, storing it effectively, and transferring it wisely to household appliances, the system offers a sustainable solution overall. Through IoT-based smart control, it lessens reliance on grid power, encourages eco-friendly living, and improves user convenience.

#### V HARDWARE DESCRIPTION

##### ARDUINO UNO

In order to create digital devices and interactive objects that can sense and control both physically and digitally, Arduino is an open-source hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits. Anyone can build Arduino boards and

distribute its software thanks to its products' GNU Lesser General Public License (LGPL) or GNU General Public License (GPL) licenses. Commercial preassembled Arduino boards and do-it-yourself (DIY) kits are both available.



Fig.2 ARDUINO UNO BOARD

### Turbo wheel



Fig3: turbo wheel.

The Turbo Wheel Micro Turbine Module serves as the primary renewable energy source for the smart home energy management system. It operates by spinning two turbine blades with mechanical motion or airflow, which powers a small generator. This generator converts the mechanical energy into DC electricity.

A battery storage module receives the generated power, controls it, and stores it for later use. This ensures that even in the absence of solar power, the smart home system will always have access to renewable energy.

### Battery Storage Module:

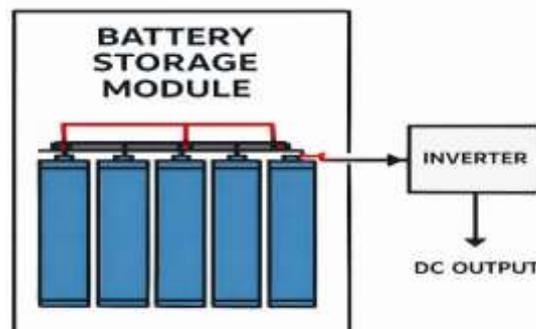


Fig.4 battery

For the system to remain stable and energy-reliable, the battery storage module is necessary. It acts as the energy reservoir in between, storing the DC electricity generated by the Turbo Wheel Micro Turbine and supplying the microcontroller and connected smart home appliances with regulated power.

- Energy buffering: By storing extra energy, this technique evens out varying turbine output.
- Power Supply Management: Gives every part of the system steady voltage and current.

- Backup Power: Provides uninterrupted operation when turbine activity is low or nonexistent.
- Charge/Discharge Control: Through controlled charging and discharging, battery health is safeguarded.

#### DHT11 Sensor Module



The smart home's temperature and humidity levels are measured by this sensor. When anomalous circumstances are found, the data is utilized to automatically regulate the fan or send out alarms.

- Temperature Monitoring: Tracks ambient temperature in real time.
- Humidity Monitoring: Measures air moisture to manage ventilation.
- Data Transmission: Sends sensor readings directly to Arduino.
- Automation Trigger: Activates appliances or alerts based on thresholds.

#### WI-FI Module



#### WiFi Module

The smart home energy management system's communication core is the Wi-Fi module. By enabling Internet of Things (IoT) connectivity, the Arduino microcontroller can receive commands from users via web or mobile applications and send sensor data and system status to a cloud platform. This guarantees that the system can be accessed and controlled from any location in the world and is not restricted to local control. Voltage of the battery.

- Light Detection: Constantly measures the amount of light in the environment.
- Signal Conversion: Provides Arduino with voltage values based on light levels.
- Automation Control: Directs Arduino to turn lights on and off in response to brightness.
- Energy Optimization: Reduces electricity consumption by only turning on lights when necessary.

#### LCD Display Module



16x2 ICC LCD Module

The smart home energy management system's local user interface is provided by the LCD Display Module. It gives users real-time insight into system performance, allowing them to keep an eye on important metrics without depending entirely on mobile apps or IoT dashboards. The LCD guarantees transparency and quick feedback for system operation by showing turbine output, battery status, temperature, humidity, and light levels.

- Real-Time Monitoring: Shows current environmental and energy sensor readings.
- User-Friendly Interface: Provides clear data for simple system evaluation.

- Local accessibility: Makes it possible to monitor without relying on the internet.
- Alert Display: Offers immediate alerts for anomalous circumstances.
- System Feedback: Shows the status of the appliance for the benefit of the user.

## VI RESULTS

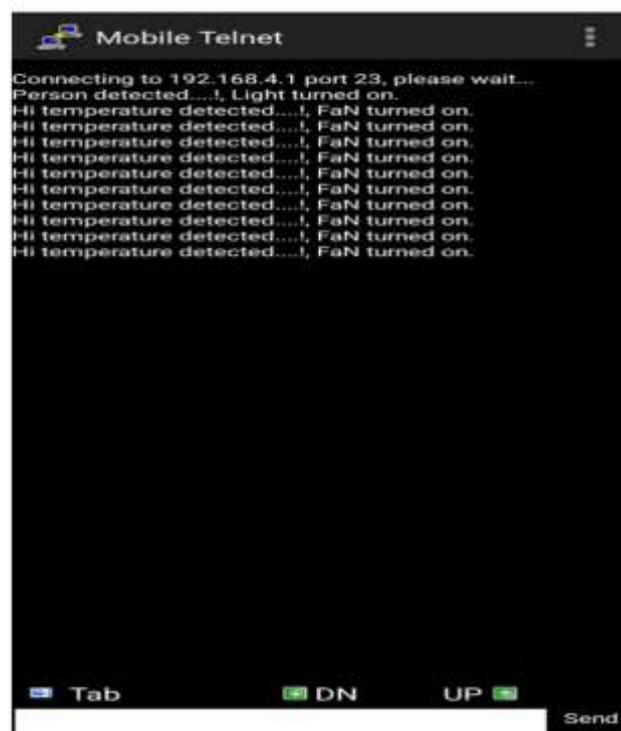
Fluid flow was successfully converted into continuous low-voltage DC power by the turbo wheel micro turbine, which was then stored in a battery and used to power domestic appliances. Based on temperature, humidity, and ambient light levels, the Arduino microcontroller automatically switched the fan and light in response to sensor inputs. Through cloud dashboards, customers can monitor turbine output, battery condition, and appliance activity thanks to the IoT module's real-time monitoring and remote-control capabilities. With an efficiency of around 70%, the system accomplished consistent voltage control, guaranteeing dependable operation for small-scale residential loads. Overall, the SHEMS optimised energy use, decreased reliance on grid electricity, and showed that incorporating micro turbines into smart home energy management is feasible.

The turbo wheel micro turbine provided continuous low-voltage DC power (5–12V), which was successfully stored in the battery and delivered to appliances.

The Arduino microcontroller responded properly to sensor inputs, automatically adjusting the fan and light based on temperature, humidity, and ambient light levels.

Through cloud dashboards, customers can monitor turbine output, battery condition, and appliance activity thanks to the IoT module's real-time monitoring and remote control capabilities. The technology ensured dependable operation for small-scale residential loads by achieving consistent voltage control with around 70% efficiency.

Overall, the SHEMS optimised energy use, decreased reliance on grid electricity, and showed that incorporating micro turbines into smart home energy management is feasible.



## VII CONCLUSION

The design and deployment of an Internet of Things (IoT)-based Smart Home Energy Management System (SHEMS) that incorporates intelligent monitoring and control technologies with a turbo wheel micro turbine as a renewable micro-generation source is demonstrated in this study. The system offers real-time monitoring, intelligent load scheduling, and remote appliance management by utilising fluid energy through the turbine and integrating it with IoT-enabled sensors, microcontrollers, and cloud-based platforms.

The shortcomings of traditional energy systems, such as dependence on centralised grids, ineffective energy distribution, and low user awareness, are successfully addressed by the suggested architecture. The system

guarantees the best use of available energy resources, lowers electricity prices, and minimises carbon emissions through intelligent load prioritisation and battery storage management.

Reliable data transfer and smooth integration with cloud services are made possible by lightweight IoT communication protocols like MQTT and CoAP. Predictive algorithms further boost performance by anticipating demand and optimising energy distribution, guaranteeing that families benefit from continuous and efficient energy supply.

The goal of sustainable smart cities, where residences actively engage in decentralised energy ecosystems, is furthered by this effort.

Future plans include for integrating the system with electric car charging infrastructure, adding blockchain-based peer-to-peer energy trading, and using artificial intelligence for sophisticated demand forecasting.

In conclusion, the IoT-based SHEMS employing a turbo wheel micro turbine bridges the gap between renewable energy adoption and intelligent energy management, providing families a scalable, efficient, and ecologically responsible alternative for modern life.

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