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Review Paper on Energy Efficient Smart City

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Abstract

Rapid urbanization and increasing energy demand have created serious challenges related to power consumption, environmental pollution, and efficient resource management in modern cities. An Energy-Efficient Smart City aims to overcome these challenges by integrating advanced technologies, renewable energy sources, and intelligent automation systems to ensure sustainable development and improved quality of life. This project focuses on the design and implementation of a smart city model that emphasizes energy efficiency, automation, and eco-friendly solutions.

The proposed smart city system incorporates innovative technologies such as wireless car charging, automatic straight-line control systems, smart dustbins, vertical wind energy generation, and solar tracking systems. Wireless car charging enables electric vehicles to be charged without physical connectors, reducing energy loss, improving safety, and enhancing user convenience. The automatic straight-line system ensures efficient traffic or path control using sensor-based automation, contributing to better transportation management and reduced energy wastage.

Smart dustbins play a vital role in waste management by automatically detecting garbage levels and providing alerts, thus maintaining cleanliness while minimizing manual effort and operational energy consumption. Renewable energy generation is achieved through vertical wind turbines, which are suitable for urban environments due to their ability to operate at low wind speeds and occupy minimal space. Additionally, the solar tracker system enhances solar power efficiency by continuously aligning the solar panel toward the direction of maximum sunlight, thereby increasing energy output compared to fixed solar panels.

Overall, the proposed Energy-Efficient Smart City model demonstrates how the integration of smart technologies and renewable energy sources can significantly reduce energy consumption, improve operational efficiency, and promote environmental sustainability. This project highlights the potential of smart infrastructure in building greener, cleaner, and more sustainable cities for the future.

1. INTRODUCTION

Rapid urbanization and continuous population growth have led to a significant increase in energy demand, environmental pollution, and pressure on urban infrastructure. Traditional city systems often rely on non-renewable energy sources and manual operations, resulting in energy

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wastage and inefficient resource management. To address these challenges, the concept of an Energy-Efficient Smart City has emerged as a modern and sustainable solution that combines advanced technology, automation, and renewable energy sources to improve the quality of urban life while reducing environmental impact.

An energy-efficient smart city focuses on optimal utilization of energy through intelligent systems, sensors, and automated control mechanisms. By integrating smart technologies, cities can reduce power consumption, minimize human effort, and ensure effective management of transportation, waste, and energy resources. The primary goal is to create a cleaner, greener, and more sustainable urban environment that supports long-term development.

This project presents a model of an Energy-Efficient Smart City incorporating innovative features such as wireless car charging, automatic straight-line systems, smart dustbins, vertical wind energy, and solar tracker technology. Wireless car charging enables electric vehicles to charge without physical connectors, improving safety, convenience, and energy efficiency while promoting the use of eco-friendly transportation. The automatic straight-line system uses sensors and control circuits to guide vehicles or paths accurately, helping to reduce traffic congestion and unnecessary energy loss.

Effective waste management is achieved through smart dustbins, which detect garbage levels automatically and indicate when collection is required, ensuring cleanliness and reducing fuel consumption during waste collection. Renewable energy generation is enhanced using vertical-axis wind turbines, which are suitable for urban areas due to their compact size, low noise, and ability to operate at low wind speeds. Additionally, the solar tracker system maximizes solar power generation by continuously adjusting the position of solar panels to follow the sun throughout the day.

Overall, the proposed smart city model demonstrates how integrating automation and renewable energy technologies can significantly improve energy efficiency, reduce environmental pollution, and support sustainable urban development.

2. LITERATURE REVIEW

With rapid urban growth and increasing energy consumption, the concept of smart cities has gained significant research interest as a sustainable solution to enhance urban functionality, optimize energy usage, and improve citizens' quality of life. A smart city integrates advanced technologies and renewable systems to create efficient, automated, and eco-friendly urban environments.

Wireless Car Charging

Wireless or inductive charging systems for electric vehicles (EVs) have been widely explored as an alternative to conventional plug-in chargers. Research by Kurs et al. (2007) demonstrated the feasibility of high–efficiency wireless power transfer (WPT) using resonant inductive coupling, showing potential for EV charging with reduced energy loss and improved user convenience. Later studies focused on dynamic wireless charging systems that can charge vehicles while in motion, thus reducing the need for frequent stops and minimizing range anxiety among EV users. These developments indicate that integrating wireless car charging within smart city infrastructure can lead to reduced fossil fuel dependency and better energy utilization.

Automatic Straight-Line Control/System

Automatic straight-line systems in transportation and process control involve using sensor networks and automated actuation for maintaining predefined paths. Previous literature

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highlights the use of infrared (IR) sensors, ultrasonic sensors, and microcontrollers for accurate path following in autonomous vehicles and robotics. Banerjee et al. (2019) presented a sensor-based line-following control technique that improves accuracy and reduces manual intervention. Such automated systems contribute to streamlined traffic flow, reduced congestion, and lower energy consumption in smart city transportation networks.

Smart Dustbins

Waste management is a crucial component of smart cities. Traditional open garbage bins lead to inefficiencies, health hazards, and increased operational costs. Smart dustbins, equipped with sensors such as ultrasonic or infrared, monitor waste levels and notify authorities when bins are full. Research by Suresh et al. (2018) demonstrated a smart waste monitoring system using ultrasonic sensors and IoT communication, resulting in optimized waste collection routes and reduced fuel usage. Studies reveal that implementing smart dustbins can significantly improve cleanliness, operational efficiency, and energy savings in urban regions.

Vertical Wind Turbines

Vertical Axis Wind Turbines (VAWTs) are suitable for urban environments due to their ability to harness wind energy at low speeds and from varying directions. Unlike traditional horizontal-axis turbines, VAWTs are compact, require minimal installation space, and are less affected by turbulent wind patterns typical in cities. Research by Tummala and Dhanalakshmi (2016) showed that, combined with solar generators, vertical wind turbines can enhance renewable energy output in smart city microgrids. Their low noise and ease of maintenance make them ideal for residential areas, contributing to decentralized power generation.

Solar Tracker Systems

Solar photovoltaic (PV) systems are a cornerstone of renewable energy generation. Fixed solar panels often fail to capture optimal sunlight throughout the day due to the changing angles of the sun. Solar tracking systems, as described by Hussein et al. (2019), automatically adjust PV panels' orientation to maintain perpendicularity with incoming sunlight, increasing energy yield by up to 30–40% compared to static panels. This efficiency boost makes solar trackers an essential technology for maximizing renewable energy contribution in smart cities.

3. ANALYSIS & SYNTHESIS

Analysis

Modern cities face major problems such as increasing energy demand, pollution, traffic congestion, and inefficient waste management. Traditional systems depend heavily on non-renewable energy and manual operations, which cause energy wastage and high operational costs.

The Analysis of This Project Shows That:

- Wireless car charging reduces dependence on fossil fuels by encouraging electric vehicle usage and minimizes power loss and safety risks.
- Automatic straight-line systems improve traffic and path control, reducing unnecessary movement and energy consumption.
- Smart dustbins optimize waste collection, reduce fuel usage, and improve urban cleanliness.
- Vertical wind energy and solar tracking systems provide clean, renewable power and increase energy generation efficiency in limited urban spaces.

ISSN: 2945-4565 VOL 05, ISSUE 01, 2026

These technologies together address key energy and infrastructure challenges in cities.

Synthesis

By integrating renewable energy sources with intelligent automation, the Energy-Efficient Smart City model creates a unified, sustainable urban system. The combination of wireless EV charging, smart transportation control, automated waste management, and hybrid renewable energy generation leads to reduced energy consumption, lower pollution, and improved public services.

This synthesis demonstrates that smart infrastructure, when properly designed and implemented, can transform conventional cities into environmentally responsible, efficient, and future-ready urban environments.

4. FUTURE SCOPE

Wireless Car Charging: In the future, wireless charging can be integrated into roads and parking areas, allowing electric vehicles to charge automatically while parked or even while moving. This will reduce the need for cables, improve safety, and support large-scale adoption of electric vehicles.

Automatic Straight Line: This system can be enhanced using AI and advanced sensors for fully autonomous vehicles and intelligent traffic control, reducing accidents, congestion, and energy loss in transportation.

Smart Dustbin: Future smart dustbins can be connected with IoT and GPS to provide real-time waste monitoring, route optimization for collection vehicles, and automatic waste segregation, leading to cleaner and more efficient cities.

Vertical Wind Turbine: Vertical wind turbines can be improved for higher efficiency and can be widely installed on rooftops, highways, and buildings to generate decentralized renewable power in urban areas.

Solar Tracker System: Advanced solar trackers equipped with smart controllers and IoT connectivity will further enhance energy generation and enable real-time monitoring, making solar power more reliable and cost-effective.

5. CONCLUSION

An energy-efficient smart city represents the future of urban living. By integrating advanced technologies, renewable energy systems, and intelligent management solutions, smart cities reduce energy consumption, protect the environment, and improve the quality of life. Systems such as wireless car charging, automatic straight-line control, smart dustbins, vertical wind energy, and solar trackers demonstrate how innovative technologies can collectively build cleaner, smarter, and more sustainable cities for future generations.

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6. REFERENCE

Smart City & Smart Technologies

1. Smart Cities: Power Electronics, Renewable Energy, and Internet of Things — Edited by Ahteshamul Haque, Akhtar Kalam & Himanshu Sharma
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2. Green and Smart Technologies for Smart Cities — Edited by Pradeep Tomar & Gurjit Kaur
   Covers green smart city technologies, including energy management, transportation, waste systems, and IoT frameworks.
3. Smart Technologies for Smart Cities — Edited by Mohammad M. Banat & Sara Paiva
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4. Enabling Technologies for Sustainable Smart Cities — Edited by Mohammad A. Matin, Sotirios K. Goudos & Emmanouil M. Tentzeris
   Discusses sustainable technologies including IoT, sensing, energy harvesting, and smart grids.