

SUSTAINABLE ROADWAY BY USING SOLAR PANEL

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ABSTRACT –

The research titled "Sustainable Roadways Utilizing Solar Panels" explores the concept of integrating solar panel technology into road infrastructure to create a renewable energy source. Solar panel roadways are an innovative solution that transforms traditional roads into multifunctional energy producers. These roadways are constructed with three distinct layers, each serving a critical purpose. The base layer forms the foundation, providing structural stability and ensuring the road can withstand vehicular loads over time. The middle layer houses the core technology, including solar cells and electronic components that convert sunlight into electricity. This layer may also incorporate sensors to monitor traffic, road conditions, and temperature, contributing to improved road safety and maintenance. The electricity produced can be utilized to power infrastructure such as streetlights, traffic signals, and electric vehicle charging stations, enhancing energy efficiency and utility. The top layer, made of durable materials like silicon carbide, protects the underlying solar cells from environmental damage and heavy traffic. Additionally, it features a non-slip surface to ensure safe driving in adverse weather conditions, such as rain or snow. By combining durability, functionality, and sustainability, solar panel roadways represent a promising step toward energy-efficient and safer transportation systems.

Key Words: Renewable energy, photovoltaic technology, upkeep, security, resilience.

1.INTRODUCTION

Solar panel roadways offer an innovative solution to sustainable energy and modern infrastructure challenges by transforming road surfaces into energy-producing platforms. This technology addresses two critical global issues: the need for renewable energy and the development of smarter, more robust infrastructure. By integrating solar cells into roads, parking areas, and other paved surfaces, these roadways provide a large-scale method to capture solar energy, serving as an alternative to conventional solar installations. The design integrates advanced materials and technologies, combining distinct physical and chemical properties to ensure efficiency, durability, and functionality. Each layer of the solar panel roadway plays a crucial role, contributing to its overall performance and sustainability.

1.1 Physical Characteristics of Solar Panel Roadways

1.1.1 Structural Stability: The foundational layer, commonly constructed from materials like concrete or asphalt, ensures the road's ability to bear vehicle loads while evenly distributing pressure across the surface.

1.1.2 Resistance to Impact and Abrasion: The uppermost layer, often composed of robust materials such as silicon carbide, provides exceptional durability. This layer resists wear caused by vehicle tires and protects against environmental impacts, including hail and debris, due to its high hardness and strength.

1.1.3 Weather Durability: Each layer is engineered to endure diverse weather conditions. The foundational layer resists temperature extremes, while the technology layer is securely sealed to protect the solar cells and electronics from moisture and environmental exposure.

1.1.4 Sunlight Penetration: The top protective layer is designed for optimal light transmission, allowing sunlight to reach the solar cells efficiently. Materials like tempered glass or specially coated transparent surfaces are commonly utilized to maximize light absorption without compromising structural integrity.

1.2 Chemical Characteristics of Solar Panel Roadways

1.2.1 Solar Cell Semiconductor Doping: The electronics layer incorporates solar cells made of silicon, a semiconductor material. These cells undergo doping with elements such as phosphorus and boron, creating a p-n junction essential for the photovoltaic effect. This junction facilitates electron movement upon exposure to sunlight, generating an electric current.

1.2.2 Corrosion Resistance: Materials used in the road, particularly the top protective layer and encapsulants surrounding the solar cells, are engineered to resist environmental corrosion. This includes protection against oxidation, UV degradation, and chemical damage from pollutants or road salts. Treated glass and silicon carbide are especially effective in preventing weathering and maintaining structural integrity over time.

1.2.3 Encapsulant Longevity: Solar cells are shielded by encapsulants like ethylene vinyl acetate (EVA), which protect against moisture and UV radiation. EVA is chemically stable and durable, preventing degradation and ensuring long-term preservation of the solar cells' functionality under prolonged environmental exposure.

1.2.4 Anti-Reflective Coatings: The top layer often features anti-reflective coatings, such as silicon nitride or titanium dioxide, to enhance sunlight absorption. These coatings

minimize reflectivity, allowing lighter to reach the solar cells. Chosen for their chemical stability under UV exposure and temperature fluctuations, these materials maintain their effectiveness over extended periods.

2. Problem Statement

1. Grasping the Technology:

Solar panel roadways combine advanced systems such as photovoltaic technology and roadway engineering. Understanding how these components work together can initially be challenging due to their complexity.

2. Financial Implications:

The development and deployment of solar panel roadways entail higher costs compared to conventional road construction. This necessitates thorough financial planning and budgeting to ensure feasibility and sustainability.

3. Managing Heat Generation:

During operation, solar panels produce heat, which can negatively impact their efficiency and lifespan. Effective heat management strategies are essential to optimize performance and ensure durability over time.

3. Material Used in this project

1. Solar Panel- Solar panels convert sunlight into electricity with varying levels of efficiency, typically ranging from 15-22% for commercially available panels. This efficiency depends on the type of material used (e.g., monocrystalline, polycrystalline, or thin-film) and the quality of the panel's construction. Once installed, solar panels generally require minimal maintenance, mostly periodic cleaning to remove dust and debris that could affect sunlight absorption. The lack of moving parts reduces the need for regular upkeep.



Fig. 1 Solar Panel

2. Silicon carbide-Silicon carbide (SiC), also known as carborundum, is a synthetic compound used in various industrial and technological applications. It is a semiconductor material with exceptional physical and electrical properties, including: High thermal conductivity, hardness, and strength Resistance to corrosion, wear, and radiation Wide bandgap energy (3.2 eV) for high-power electronics High electron mobility and saturation velocity Silicon carbide (SiC), a versatile semiconductor material, boasts exceptional physical and electrical properties, including high thermal conductivity, hardness, strength, corrosion resistance, and wide bandgap energy.

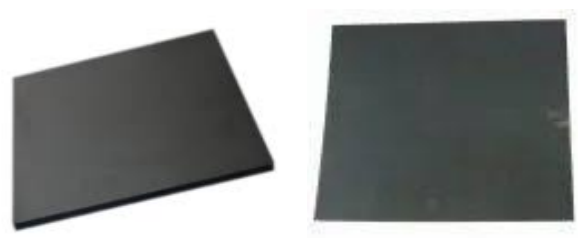


Fig. 2 Silicon carbide plate

3. Lithium-ion battery- Lithium-ion (Li-ion) batteries are a type of rechargeable battery commonly used in portable electronics, electric vehicles, and renewable energy systems. They offer high energy density, long cycle life, and low self-discharge rates. Li-ion batteries consist of a lithium cobalt oxide cathode, graphite anode, and electrolyte solution. When charged, lithium ions move from the cathode to the anode, releasing electrons and generating electricity.



Fig. 3 Lithium-ion battery

4. WIRES-WIRES (Wireless Intelligent Radio Energy Harvesting Systems) represent a cutting-edge technology that combines wireless communication and energy harvesting capabilities. WIRES enable devices to harness ambient radio frequency (RF) energy from their surroundings, converting it into electrical energy to power themselves.



Fig.4 Wires

5. Thermocol- Thermocol, also known as Expanded Polystyrene (EPS), is a lightweight, rigid, and versatile plastic material used in various applications. It is produced through the expansion of polystyrene beads, which are molded into desired shapes. Thermocol, or Expanded Polystyrene (EPS), is a versatile plastic material utilized in various industries due to its unique properties. Its production involves expanding polystyrene beads into desired shapes, resulting in a lightweight, rigid, and shock-absorbing material.



Fig.5 Thermocol

3. Objectives of the Study

3.1 Generating Renewable Energy: Utilize sunlight to produce electricity, decreasing reliance on fossil fuels and contributing to reduced greenhouse gas emissions.

3.2 Promoting Energy Self-Sufficiency: Develop a self-sustaining energy solution that minimizes dependence on conventional power grids.

3.3 Addressing Climate Change: Support environmental sustainability by lowering carbon emissions and air pollution through the use of renewable energy.

3.4 Enhancing Road Safety: Incorporate features such as integrated lighting, heating systems to prevent ice and snow accumulation, and sensors for monitoring road and traffic conditions.

4. LITERATURE REVIEW

An extensive literature survey was conducted, drawing from various credible sources. Key insights from the review are summarized as follows:

A) Er. Rajeev Ranjan:-The concept of Solar Roadways is introduced as a groundbreaking solution to address challenges like global warming, energy shortages, and aging infrastructure. This innovative idea involves replacing traditional road materials, such as asphalt and concrete, with modular solar panels. These panels are designed to generate clean energy, reducing reliance on fossil fuels and contributing to the development of a decentralized and resilient power grid.

B) Sudhir Autade:-Solar Roadways are described as interconnected, structurally robust panels capable of supporting vehicular traffic while simultaneously harvesting solar energy. Each panel, typically measuring about 1 meter by 1 meter, integrates seamlessly into a scalable system that produces renewable energy. Beyond energy generation, this technology serves as an intelligent and communicative road surface, capable of powering electric vehicles (EVs) and other infrastructure. By replacing power lines with embedded systems and incorporating smart features, Solar Roadways aim to cut greenhouse gas emissions and reduce hidden costs associated with fossil fuels.

C) A.S. Gaikwad: The increasing depletion of fossil fuel reserves and their adverse environmental effects have driven global efforts toward alternative energy sources. Solar roadways offer a pioneering solution by replacing conventional asphalt with structurally engineered solar panels. These panels not only fulfill infrastructure needs but also produce electricity, contributing to a decentralized power grid and reducing carbon emissions.

D) Alemayehu Gebremedhin -Achieving the ambitious climate goals set by the Paris Agreement necessitates a significant reduction in global CO₂ emissions. This requires a transformative shift in the current energy systems, involving substantial investment in eco-friendly energy technologies and a broader adoption of renewable energy sources.

5. Methodology

The following steps outline the approach used in this project:

A. Capturing Sunlight: Utilize solar energy as the primary source for electricity generation.

B. Silicon Carbide Plate: Employ a durable silicon carbide layer to protect the system and ensure structural integrity.

C. Solar Panels: Install photovoltaic panels to convert sunlight into electrical energy efficiently.

D. Electrical Wiring: Integrate wiring to facilitate the transmission of generated electricity.

E. Energy Storage: Use a battery system to store the harvested energy for later use.

6. RESULTS

6.1 Renewable Energy Production:

Solar roadways have demonstrated the potential to generate substantial energy from sun-exposed road surfaces. Efficiently designed solar roads equipped with high-performance photovoltaic panels can produce enough electricity to power nearby infrastructure, such as streetlights, traffic signals, or even residential areas. For example, estimates from the Solar Roadways initiative suggest that converting all U.S. roads into solar roads could produce more energy than the nation's current consumption.

6.2 Lowering Carbon Emissions:

By utilizing renewable energy instead of conventional power sources, solar roadways significantly reduce the carbon footprint of transportation infrastructure. This shift decreases dependence on fossil fuels, which are a major contributor to CO₂ emissions. The extent of emission reduction correlates directly with the energy generated and used from these solar installations.

6.3 Durability and Maintenance:

Initial trials indicate that solar panels embedded in roadways may offer better durability than traditional materials, withstanding heavy traffic and adverse weather conditions. However, their long-term performance, particularly in areas subject to extreme temperature variations, remains under evaluation.

6.4 Cost Effectiveness:

A notable challenge in implementing solar roadways is the high upfront expense of installing solar panels compared to traditional asphalt. The cost per square meter for solar roadway installation is substantially higher. However, these initial costs have the potential to be balanced over time through energy savings, lower maintenance requirements, and environmental advantages. Pilot studies indicate that as the technology scales and becomes more widespread, installation costs are likely to decrease.

Electricity generated for 4 lane N.H of 400m: -

1. Size of each solar panel: -1m*1m
2. Number of solar panels in 1 lane: -400
3. Number of solar panels in 4 lanes: -1600
4. Solar panel output: -1000w per square meter per hour (in ideal condition)
5. 200w-400w per square meter per hour (in real world condition)
6. Output for 4 lane N.H of 400m: -32000w-640000w
7. Average output: -480000w per hour

8. PHOTOGRAPHS OF THE MODEL

9.



Fig 1. MODEL OF PROJECT



Fig 2. MAKING MODEL



Fig 3. MODEL MAKING

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