Chapter 5
Energy Harvesting and Smart Highways for Sustainable Transportation Infrastructure: Revolutionizing Roads Using Nanotechnology

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ABSTRACT

The chapter explores the integration of nanotechnology, energy harvesting, and smart highways into global transportation infrastructure, aiming to create sustainable and efficient systems. Nanotechnology enhances road surface durability and functionality, offering increased strength, resilience, and self-healing properties. Energy harvesting techniques, such as piezoelectric and solar technologies, harness kinetic and solar energy from vehicular motion and sunlight, powering infrastructure, streetlights, and even the grid. Smart highways, enabled by interconnected sensors and communication systems, monitor traffic flow, adjust speed limits, provide real-time updates, and autonomously manage transportation systems. These innovations not only promise a sustainable transportation ecosystem but also catalyze economic growth, environmental preservation, and enhanced quality of life for communities worldwide.

INTRODUCTION

In the 21st century, the global community faces unprecedented challenges related to transportation, with burgeoning urbanization, population growth, and environmental concerns placing immense pressure on existing infrastructure. Traditional transportation systems heavily reliant on fossil fuels contribute significantly to air pollution, greenhouse gas emissions, and congestion, necessitating a paradigm shift towards sustainable alternatives. This has propelled the exploration and implementation of innovative technologies to transform transportation infrastructure into more efficient, eco-friendly, and resilient systems (Sultana et al., 2021).

As the world witness's rapid urbanization and population growth, cities become focal points for economic activities and human habitation. However, this surge in urban living also intensifies the demand for transportation, leading to increased traffic congestion, longer commute times, and environmental degradation. Sustainable transportation infrastructure is crucial to mitigate these challenges, ensuring that cities remain hubs of productivity without compromising the quality of life for their inhabitants (Ding & Liu, 2023).

The environmental toll of conventional transportation systems is undeniable, with vehicular emissions contributing significantly to air pollution and climate change. The need for sustainable transportation infrastructure arises from the imperative to reduce carbon footprints, embrace renewable energy sources, and foster eco-friendly practices. Addressing these environmental concerns is not only a responsibility but a necessity to ensure the health of the planet and its inhabitants. Traditional transportation systems often operate with inefficiencies, utilizing non-renewable

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