Chapter 9
Renewable Energy–Driven Smart Logistics Systems: Conceptual Model, Strategic and Feasibility Analysis

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ABSTRACT

This study examines the strategic integration of renewable energy sources into smart logistics systems to enhance operational efficiency and environmental sustainability. Based on a comprehensive literature review, it develops a conceptual model linking technological components of smart logistics, such as IoT, cyber-physical systems, cloud platforms, and decision-support mechanisms, with renewable energy solutions including solar, wind, hydropower, bioenergy, hydrogen, and geothermal energy. The study qualitatively analyzes energy–technology alignment and evaluates sustainability outcomes such as carbon emission reduction, energy cost optimization, and socio-economic benefits. A SWOT analysis and a feasibility assessment address strategic and practical considerations, while a set of hypotheses is proposed for future empirical testing. The findings highlight the need for digital–energy synergy, supportive infrastructure, and strategic policy frameworks to unlock the full potential of renewable energy-powered smart logistics.

1. INTRODUCTION

Since the Industrial Revolution, logistics processes have become highly resource-intensive, spanning the entire supply chain from production to distribution. With

DOI: 10.4018/979-8-3373-3790-6.ch009

rapid population growth, urbanization, and the expansion of global trade, the energy demands and environmental impacts of logistics have reached unprecedented levels. This has intensified the need to restructure logistics operations in line with environmental sustainability and energy efficiency principles.

In this context, smart logistics systems have emerged as a transformative solution (Sun et al., 2022). By integrating advanced technologies, including ICT, automation, AI, and data analytics, these systems aim to enhance visibility, efficiency, adaptability, and real-time decision-making across logistics networks (Alonge et al., 2023). However, their continued reliance on fossil fuels remains a critical limitation, constraining environmental performance and hindering climate action (Chu & Majumdar, 2012).

To address this, integrating renewable energy sources such as solar, wind, biomass, and geothermal into smart logistics infrastructures is gaining attention. This integration improves operational efficiency through clean, decentralized energy use while reducing greenhouse gas emissions and supporting global sustainability goals. It aligns closely with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action) (Mire et al., 2018; Denoncourt, 2020; Elavarasan et al., 2021; Ramasubramanian & Ramakrishna, 2023).

1.1. Comparative Policy Perspectives

The pace and scope of renewable energy integration into logistics differ significantly across regions, shaped by policy frameworks, technological capacities, and infrastructural readiness. In the European Union, comprehensive regulatory instruments such as the European Green Deal and emissions trading schemes have provided strong incentives for renewable deployment in transport and logistics (Karaeva et al., 2023). In the United States, large-scale policy interventions such as the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL) have catalyzed investments in clean transport corridors and logistics facilities powered by renewables (Steinberg et al., 2023). Similarly, China, Germany, Japan, and the U.S. have adopted different policy mixes to expand solar and renewable integration, reflecting variations in industrial strategies and grid capacity (Muhammed & Tekbiyik-Ersoy, 2020; Wen & Gao, 2023).

By contrast, developing economies face structural barriers such as limited capital availability, regulatory uncertainty, and inadequate energy infrastructure. Yet, these regions also present leapfrogging opportunities—bypassing intermediate fossil-based stages—through decentralized renewable systems and EV deployment in urban freight (Batinge et al., 2017; Khaleel & Chakrabarti, 2018; Eyitoyo, 2023). These comparative differences highlight that renewable–logistics integration is