Chapter 7
Smart Warehousing Technologies for Energy Efficiency: AI-Driven Optimization and Sustainability

Beslin Pajila
https://orcid.org/0000-0002-3905-2460
Anna University, India

ABSTRACT

This chapter explores the role of Artificial Intelligence (AI) in enhancing energy efficiency and sustainability in smart warehousing. AI technologies such as predictive maintenance, smart inventory management, dynamic load balancing, and automation have been shown to significantly reduce energy consumption, optimize warehouse operations, and minimize environmental impacts. AI's integration with renewable energy sources, like solar and wind, further supports sustainability goals by optimizing energy usage and reducing reliance on non-renewable power. The future potential of AI in revolutionizing warehouse energy efficiency is immense, with advancements in deep learning, edge computing, and real-time analytics. This chapter also highlights areas for future research, particularly in renewable energy integration, AI algorithm development, and scalability for small and medium-sized enterprises.

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1. INTRODUCTION

1.1 Overview of Smart Warehousing

Smart warehousing involves integrating the most current technology such as automation, data analytics, robotics and Internet of Things (IoT) with the objective of enhancing efficiency, accuracy and speed of the warehouse(Batarlienė, N., & Jarašūnienė, A 2024). It is a breakthrough of the traditional manual-driven warehouse management systems and offers new answers to the emerging need of faster delivery and high efficiency of operations. The necessity to have increased accuracy, flexibility and productivity in the modern supply chains has contributed to the development of intelligent warehouse technologies. In the very early days, warehouses were operating with the basic inventory management facility and manual processing of goods. However, as e-commerce increases, the world becomes global and consumer demands increase, there is a need to transport goods more efficiently and faster thus necessitating the use of more advanced technology integration(Van Geest, M et al., 2021).

The operations of a warehouse have changed due to smart technologies comprising robotics, AI, and IoT. The technologies allow the warehouses to work with the lowest number of people in them thus reducing the error margin and speeding up the operating time. Robotics and automated guided vehicles (AGVs) are now part of the standard at warehouses where they enable the inventory to be retrieved, orders to be picked, and materials to be transported. Moreover, the observance of the condition of the goods and the environmental factors, such as the temperature and the humidity can be tracked in real-time because of the IoT-enabled devices and sensors and it is highly valuable when it comes to delicate goods, such as pharmaceuticals and perishables.

The evolutions of the technologies have transformed the smart warehousing not only as a tool of optimization but as a must in the management of the increasingly complex needs of the contemporary supply chain. As companies are keen on becoming competitive, streamlining business processes and improving the efficiency of their warehouses, smart warehousing is a feature of business success.

1.2 Energy Efficiency in Warehousing

The use of energy in warehouses is an interesting issue, both on operational and environmental level. Warehouses usually use a lot of energy in heating, cooling, lighting as well as in running of machinery. Energy consumption in a conventional warehouse is usually ineffective because it is determined by antiquated infrastructure, ineffective insulation and inability to automate the process of controlling