Chapter 6
Unlocking Sustainable Energy: The Transformative Role of AI in Renewable Energy Technologies and Applications

Arun Agrawal
https://orcid.org/0000-0001-7233-6660
Institute of Technology and Management, Gwalior, India

Jagveer Singh
Institute of Technology and Management, Gwalior, India

Vijay Prakash Sharma
Institute of Technology and Management, Gwalior, India

Madhukar Dubey
https://orcid.org/0000-0002-0874-2039
Institute of Technology and Management, Gwalior, India

Gaurav Dubey
https://orcid.org/0009-0000-5973-3944
Institute of Technology and Management, Gwalior, India

Nitin Dixit
Institute of Technology and Management, Gwalior, India

ABSTRACT

Artificial Intelligence (AI) is a powerful catalyst for a sustainable energy future, revolutionizing the renewable energy landscape and its applications. This chapter explores AI's transformative role in the energy sector. By processing large datasets, forecasting patterns, and making real-time decisions, AI opens new possibilities in energy generation, storage, distribution, and consumption. It enhances the performance of renewable sources like solar panels and wind turbines, reducing costs and increasing output. AI-driven predictive maintenance ensures infrastructure longevity, while smart grid management improves distribution efficiency. Additionally, AI impacts sustainable urban planning, energy-efficient building designs, and electric vehicle infrastructure development. This chapter highlights AI's crucial role in advancing a greener, more efficient energy future, while also examining emerging trends and challenges.

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1. INTRODUCTION

Traditional methods in renewable energy applications have long served as the bedrock for harnessing sustainable and clean sources of power. These methods encompass a variety of established technologies that have been refined and utilized over the years. Solar photovoltaic (PV) systems, a cornerstone of renewable energy, convert sunlight into electricity through semiconductor materials, employing fixed-tilt panels or tracking systems. Wind turbines, another prevalent technology, harness kinetic energy from the wind to generate mechanical power, relying on horizontal or vertical-axis designs. Hydropower, a historically significant contributor, harnesses the energy of flowing water using dams and turbines, offering a reliable and proven source of electricity. Biomass energy relies on organic materials for heat or electricity, geothermal power taps into the Earth's internal heat, and ocean energy utilizes tidal, wave, or thermal gradients. Additionally, biogas production captures methane from anaerobic digestion, while solar thermal systems convert sunlight into heat. Each traditional method exhibits its own strengths and has contributed significantly to the diversification of renewable energy sources, playing a crucial role in the global shift toward sustainable energy practices. Ongoing advancements and the integration of emerging technologies, such as artificial intelligence, continue to enhance the efficiency and effectiveness of these established approaches. In Table -1, summarizing the comparison between AI-driven systems and traditional methods in various aspects of renewable energy applications:

Table 1. The performance of AI-driven systems compared to traditional methods in renewable energy applications

Aspect	AI-Driven Systems	Traditional Methods
Energy Forecasting	Utilizes machine learning for accurate predictions based on diverse data	Often relies on simpler statistical models
Optimization of Operations	Adjusts parameters in real-time for optimal system performance	May use rule-based approaches that may not be as adaptive
Fault Detection and Maintenance	Uses machine learning for proactive fault detection and maintenance	Relies on periodic inspections and scheduled maintenance
Grid Management	Enhances smart grid management with real-time optimization	May require manual interventions and be less responsive
Resource Allocation	Optimizes resource allocation based on data and environmental factors	Relies on fixed rules and less sophisticated algorithms

The fusion of AI with RE sources marks the dawn of a transformative era in sustainable power generation, distribution, and utilization. AI, armed with its computational prowess and predictive aptitude, has emerged as an indispensable instrument in optimizing RE systems, rendering them more efficient and dependable. This overview delves into the foundational principles and multifaceted applications of AI within the RE sector, spotlighting how this symbiotic relationship is reshaping the trajectory of the energy landscape [1].