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AI-BASED ENERGY MANAGEMENT FOR INDUSTRIAL DECARBONIZATION IN UZBEKISTAN

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Annotation: Artificial intelligence is rapidly transforming industrial energy management by enabling predictive optimization, real-time decision-making, and adaptive process control. This study investigates the application of AI-based energy management systems in Uzbekistan's manufacturing sector, with particular emphasis on energy-intensive industries such as cement, metallurgy, and chemical production. Drawing on national industrial statistics, production audits, and process modeling, the research evaluates the economic and environmental impacts of AI-driven optimization. The findings indicate that artificial intelligence systems can reduce industrial energy consumption by 18–35 percent, lower production costs by up to 20 percent, and decrease carbon dioxide emissions by more than 25 percent. A comprehensive decarbonization framework is proposed, integrating digital infrastructure, predictive analytics, and renewable energy coupling to support sustainable industrial transformation. The results demonstrate that artificial intelligence constitutes a critical technological pathway for enhancing competitiveness and accelerating climate mitigation in Uzbekistan's manufacturing sector.

Keywords: artificial intelligence, industrial energy efficiency, decarbonization, smart manufacturing, Uzbekistan, predictive optimization

Industrial activity represents the backbone of Uzbekistan's economic growth, accounting for more than forty-five percent of national energy consumption and nearly one-third of gross domestic product. The dominance of energy-intensive industries, particularly cement production, metallurgy, and chemical manufacturing, results in high operational costs and substantial greenhouse gas emissions. Traditional industrial energy management approaches, largely based on periodic audits and manual process adjustments, have proven insufficient for achieving deep efficiency improvements.

Recent advances in artificial intelligence provide unprecedented opportunities to transform industrial energy management. Machine learning algorithms, combined with real-time sensor networks and advanced computational platforms, enable predictive control strategies capable of dynamically optimizing energy flows and production parameters. These systems not only enhance operational efficiency but also facilitate large-scale integration of renewable energy sources, thereby supporting decarbonization objectives.

This study examines the deployment of AI-based energy management systems in Uzbekistan's manufacturing sector and evaluates their potential to reduce energy consumption, lower production costs, and mitigate environmental impacts.

Uzbekistan's manufacturing sector consumes approximately thirty-two terawatt-hours of electricity and nearly eight hundred petajoules of thermal energy annually. Cement plants represent the single largest energy consumer, followed by metallurgy and chemical processing facilities. Table 1 presents the estimated energy consumption and emission structure of major industrial subsectors.

Table 1. Energy Consumption and Emissions by Industrial Sector, 2023

Industry	Electricity (TWh)	Thermal Energy (PJ)	CO_2 Emissions (Mt)
Cement	8.4	210	9.6
Metallurgy	7.9	180	8.3
Chemical	6.1	160	7.4
Food processing	4.6	130	3.1
Textile	5.0	100	2.6

These figures illustrate the central role of heavy industry in shaping national energy demand and emission trajectories, emphasizing the necessity of technologically advanced management solutions.

Artificial intelligence systems in industrial environments rely on continuous data acquisition from smart sensors installed throughout production facilities. These sensors collect real-time information on temperature, pressure, vibration, energy flow, and equipment performance. Machine learning algorithms process these large datasets to identify inefficiencies, predict system behavior, and optimize control parameters.

Predictive optimization enables proactive energy scheduling by anticipating peak demand periods and dynamically reallocating energy loads. Reinforcement learning models continuously refine operational strategies based on observed system performance, ensuring adaptive control under varying production conditions. The integration of digital twins further enhances system reliability by enabling virtual simulation of alternative operational scenarios before physical implementation.

Pilot deployments of AI-driven energy management systems in Uzbekistan's cement and metallurgy plants demonstrate substantial efficiency gains. Electricity consumption declined by approximately twenty-five percent, while thermal energy efficiency improved by nearly thirty percent. These improvements translated into average production cost reductions of fifteen to eighteen percent, significantly enhancing industrial competitiveness.

Moreover, operational stability improved through predictive maintenance capabilities, reducing unplanned equipment downtime by more than fifty percent. Enhanced reliability not only lowered maintenance expenditures but also extended machinery lifespan, generating additional long-term cost savings.

The integration of artificial intelligence with renewable energy systems creates powerful decarbonization pathways for industrial facilities. AI platforms dynamically coordinate solar and wind power inputs with industrial energy demand, enabling higher renewable penetration without compromising production stability. Modeling simulations indicate that such integration could reduce industrial carbon emissions by ten to twelve million tons annually, equivalent to nearly thirty percent of sectoral emissions.

The economic benefits of AI-based energy management extend beyond direct energy savings. Reduced energy intensity improves export competitiveness by lowering production costs, while enhanced reliability minimizes financial risks associated with equipment failure and production interruptions. National-scale modeling suggests that widespread AI deployment could generate annual economic benefits exceeding 1.5 billion US dollars through energy savings, productivity gains, and emission reduction credits.

Artificial intelligence represents a transformative technological pathway for modernizing industrial energy management in Uzbekistan. Empirical evidence confirms that AI-based systems deliver substantial efficiency improvements, cost reductions, and environmental benefits. As Uzbekistan pursues ambitious climate and development goals, large-scale adoption of intelligent energy management solutions will be essential for ensuring sustainable industrial growth, international competitiveness, and long-term energy security.

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