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The role of technological innovations and artificial intelligence in improving the energy efficiency of companies

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The article examines the role of technological innovations in improving companies' energy efficiency. It studies the integration of artificial intelligence (AI) in optimizing energy consumption through real-time monitoring and predictive analytics. Innovations such as smart grids, Internet of Things (IoT) sensors, and energy storage systems are discussed. They enable companies to achieve the Sustainable Development Goals set by the United Nations General Assembly: "Affordable and clean energy" (Goal 7), "Industry, innovation, and infrastructure" (Goal 9), "Responsible consumption and production" (Goal 12), and "Climate action" (Goal 13). The use of AI-based automation and the integration of renewable energy sources are highlighted as key strategies for reducing operational costs and environmental impact.

Keywords: energy efficiency, artificial intelligence (AI), Internet of Things (IoT), smart grids, energy storage, automation, Sustainable Development Goals.

Роль технологических инноваций и искусственного интеллекта в повышении энергоэффективности компаний

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В статье рассматривается роль технологических инноваций в повышении энергоэффективности компаний. Изучается интеграция искусственного интеллекта (ИИ) в оптимизацию энергопотребления с помощью мониторинга в режиме реального времени и прогнозной аналитики. Обсуждаются такие инновации, как интеллектуальные сети, датчики интернета вещей и системы накопления энергии. Они позволяют компаниям достигать целей устойчивого развития, разработанных Генеральной ассамблеей ООН: «Недорогостоящая и чистая энергия» (Цель 7), «Индустриализация, инновации и инфраструктура» (Цель 9), «Ответственное потребление и производство» (Цель 12) и «Борьба с изменением климата» (Цель 13). Использование автоматизации на основе ИИ и интеграция возобновляемых источников энергии выделяются в качестве ключевых стратегий снижения эксплуатационных расходов и воздействия на окружающую среду.

Ключевые слова: энергоэффективность, искусственный интеллект (ИИ), интернет вещей, интеллектуальные сети, накопление энергии, автоматизация, цели устойчивого развития.

Introduction

Energy efficiency has emerged as an important priority for companies aiming to reduce operational costs, minimize environmental impact, and comply with increasingly stringent sustainability regulations. In a world characterized by rapid industrialization and growing energy demands, enhancing energy efficiency is no longer just an option, but a necessity for

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long-term competitiveness. Companies across various sectors are integrating advanced technologies to optimize their energy consumption and reduce waste.

Technological innovations, particularly those driven by artificial intelligence (AI), have played a transformative role in addressing energy inefficiency. By leveraging AI, businesses can not only monitor and predict energy usage patterns but also implement dynamic, real-time optimizations to minimize energy loss. These technologies enable companies to better align with sustainability goals while achieving financial savings. AI-driven systems, combined with smart grids, sensors, and energy storage technologies, are contributing to the integration of renewable energy sources, thus enhancing both efficiency and sustainability. The aim of this article is to explore the role of technological innovations, particularly AI, in enhancing the energy efficiency of companies.

Main part. Challenges in energy efficiency

Manufacturing, transportation, and energy production are among the largest consumers of energy, often relying on fossil fuels and outdated technologies that exacerbate energy waste. According to the annual analysis by the International Energy Agency (IEA), in 2023, the growth rate of energy intensity – the primary indicator used to assess the energy efficiency of the global economy – decreased to 1,3%, down from a higher rate of 2% in the previous year (fig. 1) [1].

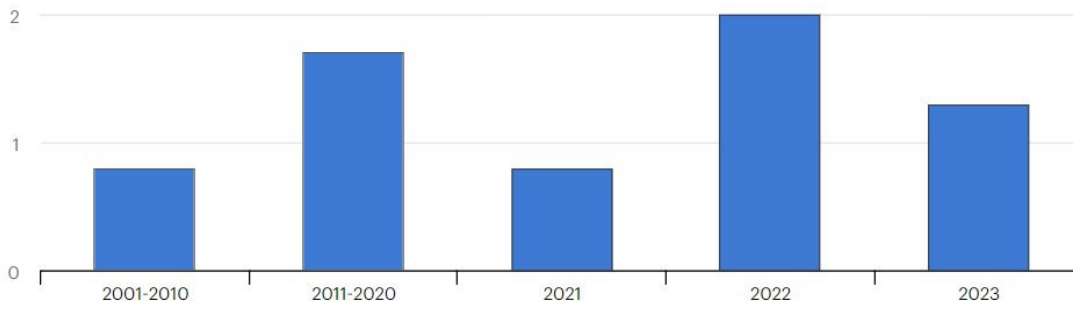

Figure 1. Annual primary energy intensity improvement, %

Excessive energy use in industrial activities leads to higher carbon dioxide (CO_2) emissions, which contribute to air pollution and global warming. This not only accelerates climate change but also imposes significant health risks on populations, particularly in urban areas where industrial activities are concentrated [2]. The extraction and consumption of non-renewable energy sources, such as coal and oil, result in the depletion of natural resources and further ecological harm, including habitat destruction and water contamination.

According to the IEA, 2023 was the hottest year on record, with temperature records also observed in 2024. Extreme heat puts significant pressure on power supply systems, requiring substantial investments in grid infrastructure and electricity generation. For example, research indicates that every 1ºC increase in the average daily temperature above 24ºC leads to a roughly 4% increase in electricity demand in Texas [3].

From an economic perspective, energy inefficiency translates into substantial financial losses for companies. It increases operational costs, as businesses are required to consume more energy to achieve the same output levels [3]. These increased costs can erode profit margins and reduce overall competitiveness in the global market. Companies that fail to optimize their energy use are exposed to fluctuating energy prices, which can add to operational uncertainty and financial instability [4]. Annual investments in energy efficiency have increased by 45% since 2020 [3].

Compounding these challenges are the growing regulatory pressures and sustainability goals that companies must meet. Governments around the world are introducing stricter environmental regulations aimed at curbing CO_2 emissions and promoting cleaner energy use. For instance, international agreements like the Paris Agreement have set ambitious targets for GHG reductions, prompting national governments to enact policies that incentivize or mandate energy-efficient practices. In 2023, the first results of the Paris Agreement implementation were reviewed, revealing that the world is on a trajectory for a global temperature rise of 2,1-2,8ºC, compared to the 4ºC projection before the agreement was adopted [5]. The Paris Agreement also emphasizes energy efficiency as a key factor in mitigating climate change, with specific targets aimed at reducing energy consumption and improving efficiency across sectors. This puts additional pressure on companies, forcing them to implement innovative technologies to reduce CO_2 emissions. At the same time, investors and consumers are increasingly prioritizing sustainability, compelling businesses to improve their environmental performance to maintain their market position and access to capital.

Technological innovations driving energy efficiency

Technological innovations play a pivotal role in enhancing energy efficiency across various sectors. Advancements such as smart grids and advanced energy storage systems allow companies to optimize their energy usage, significantly reducing waste. Through the integration of real-time data analytics and automation, industries can achieve higher levels of energy efficiency, fostering both sustainability and economic savings. Cutting-edge technologies like Internet of Things (IoT) sensors, digital twins, and intelligent building management systems have transformed traditional energy management practices, offering enhanced control and adaptability. These innovations not only facilitate compliance with environmental regulations but also contribute to significant reductions in CO_2 emissions and improvements in overall operational efficiency, aligning with the United Nations' Sustainable Development Goals, particularly "Affordable and clean energy" and "Climate action" (tabl.) [6, 7].

Table

Key technological innovations enhancing energy efficiency

Technology	Description	Application area	Benefits
Smart grids	Integrated systems for real-time energy management and distribution.	Energy distribution	Reduces energy losses, optimizes load balancing.
IoT sensors	Devices that monitor and collect data on energy usage.	Manufacturing, buildings	Enables real-time monitoring, identifies inefficiencies.
Energy storage systems	Technologies for storing excess energy, including batteries and flywheels.	Renewable energy systems	Enhances energy reliability, supports renewable integration.
Digital twins	Virtual models that simulate energy performance of physical systems.	Industrial and commercial sectors	Improves energy planning and operational efficiency.
Smart building systems	Automated systems that control heating, cooling, and lighting.	Commercial and residential buildings	Reduces energy consumption through optimized environmental control.
Variable speed drives	Devices that adjust motor speed based on demand.	Manufacturing, HVAC systems	Increases energy efficiency, reduces operational costs.
Renewable integration platforms	Software for managing and integrating renewable energy sources.	Energy utilities	Enhances renewable energy use, lowers CO_2 emissions.

From the author's perspective, the integration of advanced technologies is crucial for improving energy efficiency across a range of industries. These innovations enable a more accurate and dynamic management of energy consumption, providing businesses with the capacity to monitor and optimize their operations in real time. The adoption of such technologies is instrumental not only for regulatory compliance but also for the attainment of long-term sustainability objectives. The shift towards automation and real-time energy management systems represents a significant trend in industrial energy practices, allowing companies to better respond to fluctuating energy demands while minimizing superfluous consumption. This approach underscores the role of technology in fostering operational efficiency and environmental responsibility.

Artificial intelligence and machine learning for energy optimization

The integration of AI and machine learning (ML) into energy management systems has revolutionized the way companies optimize energy consumption. These technologies enable more accurate forecasting, real-time adjustments, and improved operational efficiency, helping industries achieve significant energy savings while reducing environmental impact. The global AI in energy market is projected to grow from $5,23 billion in 2023 to $22,92 billion by 2030, with a compound annual growth rate of 23,5% during the forecast period [8].

One of the primary contributions of AI is its ability to predict energy demand with high precision. By analyzing historical data, weather patterns, and production schedules, AI-powered systems can forecast energy needs and make adjustments to avoid overconsumption or waste. These models are particularly valuable in industries with fluctuating energy requirements, such as manufacturing, where energy demand varies depending on production cycles. Accurate forecasting allows businesses to align their energy usage more closely with actual demand, minimizing excess energy consumption and associated costs.

In addition to demand forecasting, AI and ML play a crucial role in **optimizing energy use within specific processes**. ML algorithms can analyze complex datasets generated by IoT sensors and other monitoring devices to identify patterns of inefficiency. These insights enable companies to fine-tune their operations, such as adjusting machinery performance or optimizing heating, ventilation, and air conditioning (HVAC) systems, to achieve maximum energy efficiency.

AI-driven automation also contributes to **energy optimization** by enabling **autonomous control systems**. For instance, in smart buildings, AI-based control systems can dynamically adjust lighting, heating, and cooling based on occupancy and external environmental factors. This level of automation not only enhances energy efficiency but also improves comfort and convenience for building occupants [9].

The integration of **renewable energy sources** is significantly **optimized** through the use of AI and ML technologies. These technologies can manage the variability of renewable power generation by predicting output from sources such as solar and wind, allowing for more effective energy storage and distribution [10]. By balancing supply and demand in real time, AI systems help to ensure that renewable energy is utilized efficiently and that reliance on non-renewable energy sources is minimized.

The application of AI and ML in energy optimization presents a significant opportunity for companies to enhance their operational efficiency, reduce costs, and contribute to environmental sustainability. By utilizing these technologies, businesses can contribute to achieving the United Nations' Sustainable Development Goals [11]: "Affordable and clean energy" (Goal 7), "Industry, innovation, and infrastructure" (Goal 9), and "Climate action" (Goal 13). These technologies provide a competitive advantage through more intelligent and flexible energy management strategies while simultaneously implementing responsible consumption and production practices (Goal 12).

Examples of implementing technological innovations and AI to improve companies' energy efficiency

The implementation of advanced technologies and AI to improve energy efficiency involves several critical considerations, such as the scalability of solutions, seamless integration with existing infrastructure, and effective management of real-time data. While numerous companies are investigating the potential of these tools, a few prominent American corporations have already deployed them with notable success, leading to significant enhancements in their energy efficiency.

Ford Motor Company, one of the largest automobile manufacturers globally, has been leveraging AI and advanced technologies to enhance energy efficiency across its production facilities. From 2017 to 2023, Ford reduced the total CO_2 footprint of its operations – both manufacturing and non-manufacturing – by 47% (fig. 2) [12].

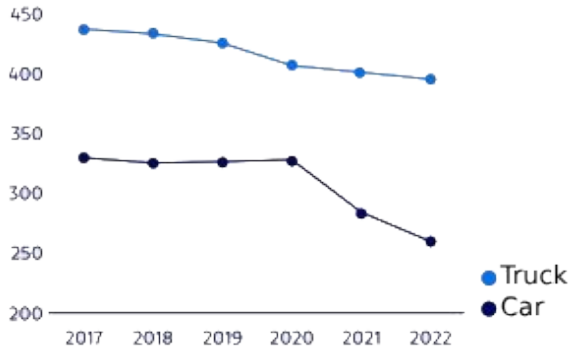

Figure 2. Ford USA real world CO_2, g CO_2/mile

AI-powered systems, including real-time energy monitoring and predictive maintenance, have allowed Ford to optimize energy use, particularly in energy-intensive processes like painting and assembly, significantly improving operational efficiency.

In addition to these efforts, Ford has committed to powering all its global manufacturing plants with 100% carbon-free electricity by 2035. This goal will be achieved through a diverse energy mix, including wind, solar, nuclear, geothermal, biomass, and hydroelectric power. As of 2023, Ford's global manufacturing operations already utilized 50,8% renewable electricity and 70,5% carbon-free electricity, reflecting its strong commitment to environmental sustainability [12].

By integrating these sustainable practices, Ford is actively contributing to the United Nations' Sustainable Development Goals, particularly "Affordable and clean energy" (Goal 7), "Industry, innovation, and infrastructure" (Goal 9), and "Climate action" (Goal 13).

Honeywell, a global leader in industrial technology, has implemented AI-powered solutions to optimize energy efficiency across its manufacturing and industrial processes. The company uses advanced AI systems in its energy management platforms, such as Honeywell Forge, which collects data from sensors and equipment in real time to monitor energy usage. In 2022, Honeywell reported implementing over 6,300 sustainability projects since 2010, resulting in an estimated $100 million in annual savings [13]. Honeywell Forge analyzes operational data to detect inefficiencies and provides actionable insights to reduce energy consumption in industrial facilities, contributing to significant reductions in the company's energy intensity, which improved by approximately 70% since 2004.

In addition to its own operations, Honeywell provides AI-driven energy solutions to other industries, helping manufacturers optimize heating, cooling, and power usage in large-scale production environments. These systems have helped avoid the potential release of 326

million metric tons of CO_2 equivalent into the atmosphere since 2010 [13]. Honeywell's commitment to integrating AI into industrial processes aligns with several of the United Nations' Sustainable Development Goals, particularly "Affordable and clean energy" (Goal 7), "Industry, innovation, and infrastructure" (Goal 9), "Responsible consumption and production" (Goal 12), and "Climate action" (Goal 13), demonstrating the potential for advanced technology to drive energy efficiency in large-scale industrial operations while reducing operational costs and supporting global sustainability efforts.

Amazon has deployed AI and advanced automation systems across its logistics network and warehouses to reduce energy consumption. By integrating AI-driven robotics, smart lighting, and HVAC optimization systems, Amazon can control energy usage based on real-time operational needs, such as adjusting temperature and lighting according to occupancy and workload. In 2023, Amazon reached its goal of matching 100% of its global operations' electricity consumption with renewable energy, seven years ahead of its original 2030 target. Amazon successfully reduced energy consumption in its cloud services: AWS achieved an 11% reduction in emissions and 100% use of renewable energy [14]. Through these efforts, Amazon has significantly reduced energy consumption across both its physical and digital operations, contributing to its sustainability goals. The company also invested in expanding its energy-efficient infrastructure, with improvements in lighting and energy monitoring systems, further reducing its CO_2 footprint. Amazon’s sustainability initiatives are closely tied to the "Affordable and clean energy" (Goal 7), "Industry, innovation, and infrastructure" (Goal 9), "Responsible consumption and production" (Goal 12), and "Climate action" (Goal 13), positioning the company as a leader in sustainable energy practices across both industrial and digital sectors.

Conclusion

The integration of technological innovations, particularly AI, plays a transformative role in improving the energy efficiency of companies across various industries. AI-driven systems can analyze vast amounts of data from sensors, enabling more precise energy management and reducing waste. This not only leads to significant cost savings but also supports sustainability initiatives by lowering CO_2 emissions. Moreover, AI contributes to the seamless integration of renewable energy sources, such as solar and wind power, ensuring efficient energy use while minimizing dependence on fossil fuels.

The benefits of technological innovations extend beyond AI to include advanced tools like smart grids, energy storage systems, and IoT devices. These technologies allow companies to monitor energy consumption at granular levels and implement dynamic solutions to enhance operational efficiency.

REFERENCES

1. Annual primary energy intensity improvement, 2001-2023, and by scenario, 2022-2030 // IEA. – URL: https://www.iea.org/data-and-statistics/charts/annual-primary-energy-intensity-improvement-2001-2023-and-by-scenario-2022-2030 [Accessed 28th August 2024].

2. Kristian A. Application of AI in Optimizing Energy and Resource Management: Effectiveness of Deep Learning Models / A. Kristian, T.S. Goh, A. Ramadan, A. Erica, S.V. Sihotang // International Transactions on Artificial Intelligence. – 2024. – Vol. 2. – No. 2. – pp. 99-105.

3. Energy Efficiency 2023 // IEA. – URL: https://www.iea.org/reports/energy-efficiency-2023 [Accessed 29th August 2024].

4. Konstantinov D. The future of refrigeration systems: integration of smart technologies and the Internet of things / D. Konstantinov // The scientific online journal «Stolypinsky Bulletin». – 2024. – Vol. 5. – No. 7. – pp. 2652-2663.

5. Technical dialogue of the first global stocktake. Synthesis report by the co-facilitators on the technical dialogue // United Nations Climate Change. – URL: https://unfccc.int/documents/631600 [Accessed 30th August 2024].

6. Stepanov M. Impact of efficient use of frequency converters on reducing industrial energy consumption / M. Stepanov // Вестник науки. – 2024. – Vol. 4. – No. 6 (75). – pp. 1241-1250.

7. Stepanov M. The application of machine learning for optimizing maintenance processes and energy management of electric drives / M. Stepanov // Cold Science. – 2024. – No. 2. – pp. 22-30.

8. Artificial Intelligence in Energy Market by Deployment Type (On-premise, Cloud), by Application (Robotics, Renewables Management, Safety and Security, Infrastructure), and Region, Global trends and forecast from 2024 to 2030 // Exactitude Consultancy. – URL: https://exactitudeconsultancy.com/reports/41028/artificial-intelligence-in-energy-market/ [Accessed 1st September 2024].

9. Kendjaev A. Methods of motivation and personnel management in the multicultural environment of the USA / A. Kendjaev // Cold Science. – 2024. – No. 5. – pp. 37-44.

10. Ibekwe K.I. Energy efficiency in industrial sectors: A review of technologies and policy measures / K.I. Ibekwe, A.A. Umoh, Z.Q.S. Nwokediegwu, E.A. Etukudoh, V.I. Ilojianya, A. Adefemi // Engineering Science & Technology Journal. – 2024. – Vol. 5. – No. 1. – pp. 169-184.

11. The 17 Goals // United Nations. – URL: https://sdgs.un.org/goals [Accessed 1st September 2024].

12. On The Road to Better. Helping Build a Better World. Integrated Sustainability and Financial Report 2024 // Ford. – URL: https://s201.q4cdn.com/693218008/files/doc_financials/2023/ar/2024-Ford-Integrated-Sustainability-and-Financial-Report_Final.pdf [Accessed 2nd September 2024].

13. The Future Is What We Make It. 2023 Annual Report // Honeywell. – URL: https://honeywell.gcs-web.com/static-files/db88bc82-eba8-4d83-ae20-2eb44bc337e6 [Accessed 3rd September 2024].

14. Reports: 2023 Sustainability Report // Amazon Sustainability. – URL: https://sustainability.aboutamazon.com/reporting [Accessed 5th September 2024].

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