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THE ROLE OF DIGITAL TECHNOLOGIES IN CLIMATE CHANGE MANAGEMENT: STRATEGIES FOR MINIMIZING THE ENVIRONMENTAL IMPACT OF USA COMPANIES

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РОЛЬ ЦИФРОВЫХ ТЕХНОЛОГИЙ В УПРАВЛЕНИИ КЛИМАТИЧЕСКИМИ ИЗМЕНЕНИЯМИ: СТРАТЕГИИ МИНИМИЗАЦИИ ЭКОЛОГИЧЕСКОГО ВОЗДЕЙСТВИЯ АМЕРИКАНСКИХ КОМПАНИЙ

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Abstract. The article examines the role of digital technologies in climate change management and reducing the environmental impact of U.S. companies. Innovations such as artificial intelligence, the Internet of Things, and big data are analyzed for their ability to help companies minimize CO_2 emissions, optimize resource use, and improve energy efficiency. Challenges companies face when implementing digital solutions: high initial costs, integration difficulties, and regulatory complexities, are discussed. Strategies for overcoming these barriers to achieve sustainable development are proposed.

Аннотация. В статье рассматривается роль цифровых технологий в управлении климатическими изменениями и снижении экологического воздействия американских компаний. Анализируются такие инновации, как искусственный интеллект, Интернет вещей и большие данные, которые помогают компаниям минимизировать выбросы CO_2, оптимизировать использование ресурсов и повысить энергоэффективность. Обсуждаются проблемы, с которыми сталкиваются компании при внедрении цифровых решений: высокие первоначальные затраты, трудности с интеграцией и сложности регулирования. Предлагаются стратегии их преодоления для достижения устойчивого развития.

Keywords: digital technologies, climate change, artificial intelligence, Internet of Things, big data, sustainable development, decarbonization.

Ключевые слова: цифровые технологии, изменение климата, искусственный интеллект, Интернет вещей, большие данные, устойчивое развитие, декарбонизация.

Climate change represents one of the most serious challenges facing humanity in the 21st century. The increasing frequency of extreme weather events, rising global temperatures, and the depletion of natural resources underscore the need for comprehensive strategies to mitigate environmental damage. Digital technologies hold significant potential in the fight against climate change, as these innovations provide powerful tools for monitoring, analyzing, and reducing greenhouse gas emissions and resource consumption.

Т. 10. №10 2024
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In the USA, corporations play an important role in shaping the country's response to climate change. Many American companies have begun to adopt advanced digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics to improve their environmental performance and reduce carbon emissions. These technological solutions not only enable more efficient energy use and waste reduction but also allow companies to meet increasingly stringent environmental regulations and market expectations for sustainability. The goal of this article is to explore how American companies are utilizing digital technologies to combat climate change and minimize environmental impact.

Main part. The intersection of digital technology and environmental sustainability

Climate change is becoming an increasingly urgent global issue, with the past decade (2011-2020) being the warmest on record for both land and ocean. Each successive decade since the 1990s has been characterized by higher temperatures than the previous ones, driven by the increasing concentration of greenhouse gases in the atmosphere. Marine heatwaves have become more frequent and intense, affecting around 60% of the ocean's surface annually during this period [1]. Glaciers and polar ice sheets are losing mass at an alarming rate, with Greenland and Antarctica losing 38% more ice compared to the previous decade. These changes are not only transforming ecosystems but also intensifying extreme weather events, leading to devastating consequences for food security, human mobility, and national development (Figure 1).

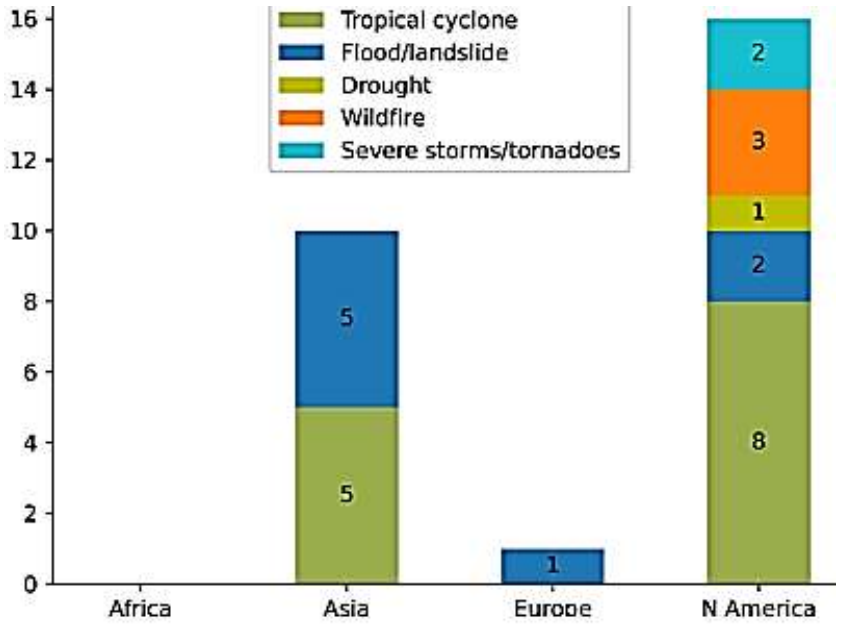

Figure 1. Number of reported disasters with more than $10 billion in economic losses by disaster type and region [1]

The rapid advancement of digital technologies has revolutionized the approach to managing climate change, offering new tools that enhance the efficiency and effectiveness of environmental sustainability efforts. Among the most impactful innovations are AI, the IoT, and big data analytics, which collectively provide powerful solutions for monitoring, predicting, and mitigating the effects of climate change. These technologies are enabling companies to implement data-driven strategies that not only reduce greenhouse gas emissions but also improve the overall efficiency of resource use [2].

An important tool in climate change management is the use of AI, particularly for processing vast amounts of environmental data and generating predictive models. AI algorithms can analyze

Т. 10. №10 2024
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complex climate patterns, forecast potential environmental impacts, and optimize energy use across industries [3]. For instance, AI-powered systems can automatically adjust heating, ventilation, and air conditioning (HVAC) systems in buildings, leading to significant reductions in energy consumption. In industrial applications, AI enhances process optimization, reducing waste and improving the efficiency of resource use in manufacturing and logistics. By identifying inefficiencies and recommending corrective actions in real time, AI helps companies achieve lower energy consumption and minimize their carbon footprint.

The IoT further complements AI by providing real-time data through connected devices and sensors. It enables companies to monitor energy usage, emissions levels, and environmental conditions at a granular level. For example, sensors installed in industrial facilities can continuously track emissions and energy consumption, allowing companies to identify inefficiencies and adjust operations accordingly. Smart grids, which integrate IoT technology, allow for real-time balancing of energy supply and demand, optimizing energy distribution and reducing losses in transmission [4]. IoT's ability to provide continuous monitoring enables companies to act proactively, preventing waste and ensuring more efficient resource use. IoT plays a pivotal role in managing renewable energy sources by coordinating the integration of solar and wind energy into national grids, thus contributing to a more sustainable energy landscape.

Big data analytics provides a foundational support system for both AI and IoT, enabling the processing of massive datasets collected from various sources. By analyzing these datasets, companies can identify long-term trends, monitor environmental impacts, and assess the effectiveness of sustainability initiatives. Big data analytics allows businesses to measure their carbon footprint with precision, offering insights into which areas of their operations are the most resource-intensive and carbon-emitting. This data-driven approach is essential for setting accurate sustainability targets and tracking progress. Big data facilitates the development of predictive models for climate risk management, helping companies prepare for and mitigate the impacts of extreme weather events and resource shortages. By transforming raw data into actionable insights, big data analytics enhances decision-making processes and supports the strategic deployment of sustainability initiatives.

Digital technologies such as AI, IoT, and big data analytics are transforming the way companies address climate change and environmental sustainability. These technologies not only provide immediate environmental benefits but also equip companies to anticipate and adapt to future climate-related challenges, positioning them as leaders in the transition to a more sustainable economy.

Digital strategies adopted by USA companies

By leveraging innovations such as AI, big data, and the IoT, businesses across diverse industries are implementing effective strategies to meet sustainability goals and combat climate change. General Motors (GM), one of the largest automobile manufacturers in the world, is increasingly relying on digital technologies to reduce its environmental impact. The company has committed to transitioning to electric vehicles (EV) as part of its long-term sustainability strategy. GM uses advanced data analytics to optimize production processes and minimize resource waste at its factories. Additionally, the company has implemented IoT sensors in its manufacturing facilities to monitor energy consumption and reduce emissions in real time. As part of its broader sustainability objectives, GM aims to reduce Scope 1 and Scope 2 greenhouse gas emissions from its operations by 72% by 2035, compared to its 2018 baseline (Figure 2).

Scope 1 emissions refer to direct emissions from sources that are owned or controlled by the company, such as emissions from fuel combustion in GM’s manufacturing processes. Scope 2 emissions are indirect emissions from the generation of purchased electricity, steam, heating, and

Т. 10. №10 2024
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cooling that GM uses in its operations. Reducing these emissions is central to GM's efforts to minimize its environmental impact and move toward carbon neutrality.

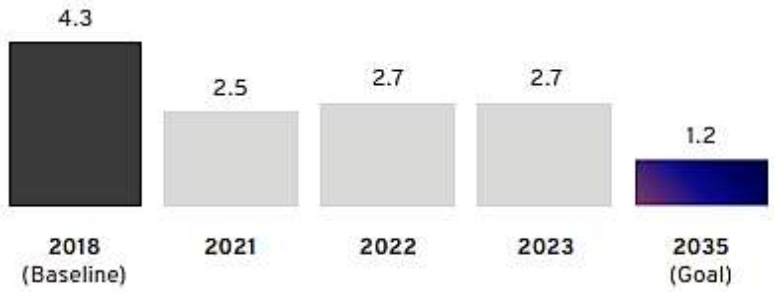

Figure 2. Absolute Scope 1 and 2 emissions of GE, million metric tons CO2 [5]

Under its digital-first strategy, GM continues to enhance energy efficiency at its facilities while improving the lifecycle management of its EV production. GM also aims to divert more than 90% of its operational waste from landfills, incinerators, and energy recovery facilities by 2025, based on its 2018 baseline. These measures are critical as the company advances toward its ambitious goal of achieving carbon neutrality in both products and operations by 2040. By leveraging digital innovations, GM is well-positioned to play a leading role in the automotive industry's transition to a more sustainable future.

Johnson & Johnson (J&J), a corporation in the pharmaceutical, medical device, and consumer health sectors, has adopted a sustainability strategy, using digital tools to minimize its environmental impact. J&J utilizes AI and IoT technologies to improve energy management and reduce waste at its manufacturing facilities. The company employs digital sensors at its plants to track energy and water consumption in real-time, allowing for timely adjustments to reduce waste. In addition, J&J uses big data analytics to optimize its supply chain, lower transportation emissions, and improve resource efficiency. By integrating these technologies, the company aims to reduce its carbon footprint and water consumption, with the goal of achieving carbon neutrality by 2030.

To further support this strategy, J&J has set clear sustainability goals. By 2025, the company plans to source 100% of its electricity needs from renewable sources. In 2023, this figure has already reached 100% in the USA, while globally, including all its subsidiaries, it stands at 87%. By 2030, J&J aims to reduce absolute Scope 1 and Scope 2 greenhouse gas emissions by 44% compared to a 2021 baseline. Since 2021, the company has already reduced these emissions by 23%, from 574,165 metric tons of CO_2 in 2021 to 442,880 metric tons of CO_2 in 2023. The company continues to invest in energy-efficient processes and decarbonization efforts at its facilities, allocating up to $40 million annually (https://lyl.su/R7U3).

J&J also leverages scientific data and detailed emissions data from its supply chain to better engage with its largest suppliers, helping them reduce emissions and set meaningful reduction targets. Through this comprehensive approach, combining digital innovation with ambitious sustainability goals, J&J is taking a leading role in reducing environmental impact while maintaining operational efficiency.

PepsiCo, a global leader in the food and beverage industry, has adopted digital strategies to drive sustainability across its supply chain. The company uses IoT sensors and big data analytics to monitor water and energy usage at its manufacturing plants. By utilizing real-time data, PepsiCo can identify inefficiencies in its production processes and make necessary adjustments to reduce energy consumption and waste. In 2023, PepsiCo achieved a 25% improvement in water-use efficiency at its high water-risk company-owned locations compared to a 2015 baseline, meeting its 2025 goal two years ahead of schedule (https://lyl.su/RVHC). Moreover, PepsiCo replenished

Т. 10. №10 2024
https://doi.org/10.33619/2414-2948/107

approximately 69% of the water used in its company-owned manufacturing facilities in high water-risk watersheds, equating to over 12 billion liters of water.

PepsiCo has also developed AI-powered models to optimize its agricultural practices, reducing water usage and minimizing the environmental impact of sourcing raw materials. The company's digital strategy extends to its logistics network, where AI is used to optimize transportation routes and lower emissions from its delivery fleet. In 2023, PepsiCo's fleet traveled over 1,2 billion miles worldwide, and the company continued to expand its use of electric vehicles, driving over 3 million zero-emission electric miles.

PepsiCo's commitment to leveraging digital technologies to enhance sustainability is further reinforced by its goal to achieve net-zero emissions by 2040, with a 33% reduction in Scope 1 and Scope 2 greenhouse gas emissions already achieved in 2023 compared to the 2015 baseline.

Challenges in implementing digital solutions

The integration of digital technologies into sustainability strategies presents substantial advantages, yet several challenges impede their widespread implementation across various industries. These challenges primarily encompass technical, regulatory, and financial barriers. In the USA context, the complexity is heightened by sector-specific obstacles, particularly in industries characterized by entrenched operational practices and legacy systems. The deployment of such technologies in these sectors requires overcoming significant structural and operational inertia. Table 1 outlines the primary challenges faced by American companies as they endeavor to incorporate digital solutions aimed at minimizing environmental impact.

Table

KEY CHALLENGES IN IMPLEMENTING DIGITAL SOLUTIONS FOR SUSTAINABILITY AND MITIGATION STRATEGIES [6, 7]

Challenge category	*Description*	*Mitigation strategies*
Technical challenges	Integrating IoT, AI, and big data into existing infrastructure can be complex and costly. Many older facilities are not equipped for advanced digital technologies, requiring substantial upgrades. Data security and privacy concerns arise due to real-time data sharing across systems.	Investing in scalable infrastructure upgrades, implementing robust cybersecurity measures, and partnering with tech providers to optimize integration processes.
Regulatory challenges	The USA regulatory landscape is complex, with federal, state, and local laws affecting emissions, data privacy, and digital systems. Regulatory changes can disrupt long-term strategies, and compliance demands significant resources.	Establishing dedicated compliance teams, leveraging legal expertise, and advocating for clear, consistent regulations at both state and federal levels.
Financial challenges	The high upfront costs for adopting digital technologies are a significant barrier, especially for small- and medium-sized enterprises (SMEs). Achieving a clear return on investment (ROI) may take years, while government incentives are often limited or inconsistent across regions.	Securing financial incentives through government programs, forming public-private partnerships, and conducting ROI analyses to align digital investments with long-term business goals.
Barriers in the USA market	Different industries face distinct challenges. For example, the energy and heavy manufacturing sectors often rely on legacy systems that are expensive to modernize. Moreover, a lack of skilled workers in these industries can hinder the effective deployment of digital technologies.	Offering workforce development programs, partnering with educational institutions to train employees, and adopting phased approaches to digital transformation in capital-intensive industries.

Т. 10. №10 2024
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The integration of digital technologies into sustainability strategies is a complex yet necessary process for USA companies aiming to minimize their environmental impact. Although challenges related to technical, regulatory, and financial factors may complicate this transition, addressing these barriers is essential for the long-term effectiveness of environmental management [8]. Successful implementation requires strategic investments in infrastructure and workforce development, as well as close collaboration with regulators and technology providers. Despite the obstacles, the adoption of digital solutions is crucial for enhancing operational efficiency, reducing emissions, and achieving sustainability goals.

Conclusion

Digital technologies play a pivotal role in managing climate change and reducing the environmental impact of USA companies. By leveraging innovations such as AI, IoT, and big data analytics, organizations across various sectors are enhancing their sustainability efforts, improving energy efficiency, and lowering carbon emissions. These technologies provide real-time monitoring, predictive capabilities, and optimization of resources, enabling companies to meet stringent environmental regulations and achieve long-term sustainability goals. However, technical, regulatory, and financial challenges persist, necessitating strategic investments and collaborations.

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