International Journal of Computer Science and Information Technology
ISSN: 3005-9682 (Print), ISSN: 3005-7140 (Online) | Volume 6, Number 2, Year 2025
DOI: https://doi.org/10.62051/ijcsit.v6n2.08
Journal homepage: https://wepub.org/index.php/IJCSIT/index

The Intelligent Optimization of Energy Systems and Social Value: The Contribution of Edge Computing Technology to Sustainable Development Goals

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ABSTRACT

As global energy demand continues to grow and environmental challenges escalate, traditional energy management models face significant challenges. Smart optimization of energy systems has emerged as a critical approach to drive energy transition and sustainable development. Edge computing, as an emerging technology, decentralizes data processing to the edge nodes of energy systems, enabling real-time data collection, processing, and intelligent decision-making, which enhances the efficiency and accuracy of energy management. This study focuses on the application of edge computing in energy systems, exploring how intelligent optimization strategies can improve energy efficiency, reduce costs, and promote a green low-carbon transformation. The research analyzes key application areas of edge computing in energy systems, such as smart grids, energy resource management, load scheduling, and demand response. By utilizing real-time monitoring and big data analytics, edge computing optimizes energy distribution, balances loads, predicts energy demand, and automatically adjusts system operations, thereby improving system responsiveness. The study also examines edge computing's contribution to sustainable development goals, particularly in advancing a green low-carbon economy, enhancing energy system flexibility, and addressing climate change. Additionally, the socio-economic impact of edge computing is explored, highlighting its potential to drive industrial upgrading, create jobs, and stimulate economic development. This research underscores the importance of edge computing in the energy internet and proposes a strategic framework for the integration of energy systems and sustainable development, offering both theoretical insights and practical guidance for global energy transformation.

KEYWORDS

Energy systems; Intelligent optimization; Edge computing; Sustainable development

1. INTRODUCTION

With the rapid development of the global economy and the deepening of industrialization, energy demand continues to rise, particularly during the extraction, transportation, and utilization of traditional energy, which places significant pressure on the environment. The escalating global climate change issue, driven by increased greenhouse gas emissions, presents unprecedented challenges in the energy sector. To address these issues, countries worldwide are promoting energy transition, aiming to shift from traditional fossil fuels to renewable energy sources. In this context, the energy internet has emerged as an innovative energy management model, playing a vital role in the global energy system's upgrade and optimization. The core goal of the energy internet is to drive efficient energy utilization and sustainable development through the integration of information technology, intelligence, and distributed energy resources, enabling optimized energy allocation and intelligent dispatching.

In this framework, edge computing, as an emerging information processing architecture, offers significant advantages in data processing, storage, and analysis, providing robust support for the smart development of the energy internet. By decentralizing data processing from traditional centralized cloud platforms to edge nodes closer to data sources, edge computing enables efficient real-time data collection and processing for energy systems. This technology reduces data transmission latency, improves the response speed and decision-making efficiency of energy management systems, and optimizes energy resource allocation and scheduling. Edge computing has shown broad potential in various applications within the energy internet, including smart grids, demand response, and distributed energy management.

Specifically, edge computing not only enhances the operational efficiency and intelligence of energy systems but also plays an increasingly critical role in facilitating the green low-carbon transition and addressing climate change. As global demands for energy sustainability and environmental protection grow stricter, the application of edge computing in energy systems has become a crucial technological support for achieving energy transition goals. Additionally, edge computing can profoundly impact the socio-economic landscape by advancing industrial digitization, promoting green economic growth, and supporting sustainable development across various sectors. Therefore, this study focuses on the application of edge computing in energy systems, exploring its key role in intelligent optimization and achieving sustainable development goals, as well as its broad socio-economic impacts, aiming to provide theoretical foundations and practical guidance for future energy system design and policy development.

The objective of this study is to explore how edge computing, through technological innovation, can promote the intelligent optimization of energy systems to achieve more efficient, greener, and sustainable energy management. The research will also examine the role of edge computing in driving socio-economic development, particularly in optimizing industrial structures, boosting employment, and supporting green economic transformation. Through a systematic analysis of edge computing technology, this study aims to offer new academic perspectives and theoretical frameworks for related fields, while also providing guidance for technology selection and policy formulation in practical applications.

2. CORE APPLICATIONS OF EDGE COMPUTING IN ENERGY SYSTEMS

Edge computing has become a key enabler of the transformation in energy management. As energy systems evolve and smart grid technologies advance, traditional centralized computing architectures are increasingly unable to meet the real-time, flexible, and efficient needs of modern energy systems. Edge computing addresses these limitations by shifting data processing and decision-making to edge nodes closer to data sources, improving data processing speed and efficiency. (Shi, Wei Song et al., 2019)This localized approach enhances the system's responsiveness, stability, and security.

In smart grid applications, edge computing plays a vital role. It enables real-time monitoring and analysis of key parameters like voltage, current, and frequency at critical grid points, ensuring faster responses to fluctuations. This reduces latency, improves real-time scheduling, and helps manage the variability of renewable energy sources. For example, during the integration of wind or solar energy, edge computing can predict energy production and adjust the grid's operation based on demand changes, preventing system overloads and ensuring efficient grid operation.

In global energy management, edge computing also proves advantageous. As global energy resources (e.g., solar, wind, storage) expand, traditional centralized systems struggle with slow responses and inefficient scheduling. By deploying edge computing nodes near energy production and consumption points, real-time energy data collection and processing are possible. This improves load balancing and reduces reliance on cloud systems, enhancing the overall efficiency and reliability of the energy network.

Edge computing also optimizes load scheduling and demand response. Traditional centralized load management faces delays and inaccuracies, especially when dealing with sudden fluctuations in demand. (Edge Computing Industry Alliance & Industrial Internet Industry Alliance, 2017) Edge computing provides real-time monitoring and dynamic adjustments to power usage, optimizing electricity consumption and reducing grid imbalances. This helps improve grid sustainability and efficiency.

Finally, edge computing improves energy efficiency by monitoring energy consumption and equipment performance. In industries, it can identify inefficiencies and make automatic adjustments to optimize energy use. In buildings, edge computing can adjust systems like HVAC, lighting, and security to minimize waste and optimize energy efficiency.

In conclusion, edge computing enhances the intelligence, flexibility, and efficiency of energy systems. By decentralizing processing power, it supports distributed energy systems, smart grids, load scheduling, and demand response, contributing to the achievement of green, low-carbon, and sustainable development goals. It plays a critical role in the transformation and digitalization of the energy sector.

3. EDGE COMPUTING'S CONTRIBUTION TO SDGS

Edge computing technology is gaining widespread recognition in academia and industry for its indirect contributions to achieving Sustainable Development Goals (SDGs), particularly in promoting green low-carbon transitions, improving energy efficiency, and enhancing socio-economic sustainability. The increasing global challenges of environmental change and resource pressures make SDGs a key focus of national policies and corporate strategies. The digitalization and customization of energy systems have become essential pathways to achieving these goals. (Sun, Yi et al., 2018) As an innovative computing architecture, edge computing enhances computational power by moving data processing and decision-making closer to the network edge, significantly improving the responsiveness and flexibility of energy systems, thus providing efficient technological support for global sustainability.

First, edge computing has promising applications in advancing the green low-carbon economy. Traditional energy management systems face issues like response delays and inefficient energy optimization, hindering the green transition. By shifting data processing closer to energy devices or consumption points, edge computing eliminates these delays and enables real-time adjustments of energy production, demand, consumption, and storage. (He, Zhengyuan et al., 2020) With the aid of intelligent algorithms, edge computing can optimize the integration and utilization of renewable energy sources (e.g., solar, wind), especially addressing their intermittency and volatility. It can predict energy demand based on historical and real-time data, balancing supply and demand to reduce energy waste and minimize reliance on conventional energy sources, driving the decarbonization of energy systems. Additionally, edge computing enhances overall energy efficiency, reduces consumption, and supports carbon emission reduction, advancing the development of a low-carbon economy.

Secondly, edge computing plays a critical role in enhancing energy system flexibility and addressing climate change. As extreme weather events and fluctuating energy demand become more common, energy systems need greater foresight and flexibility to manage uncertainty and instability. Edge computing, through localized data processing and decision-making, allows energy systems to respond more effectively to external changes. (Wang, Tonghe et al., n.d.) In smart grid applications, edge computing can monitor grid load, frequency, and storage status in real-time, optimizing the grid’s operation to ensure stable and secure power supply. This "edge-based" standardization greatly enhances the grid's ability to respond to emergencies, such as power outages or sudden load changes, improving system resilience and reliability, thus supporting climate change adaptation strategies.

Additionally, edge computing contributes to socio-economic sustainability, particularly in driving industrial upgrades, creating jobs, and boosting social productivity. As the digital transformation of energy accelerates, edge computing is not only fostering the smart transformation of the energy industry but also creating new industries in data processing, analysis, optimization, and intelligent control. These emerging industries generate numerous employment opportunities, particularly in high-tech, data science, and energy management sectors, promoting the green transformation of the economy and high-quality development. The widespread application of edge computing also enhances energy management in traditional industries and buildings, optimizing energy usage through real-time monitoring and automated control, further advancing the low-carbon transition and industrial upgrading. Moreover, edge computing supports the development of smart manufacturing and smart cities, improving resource utilization and production efficiency, which in turn strengthens the sustainability of socio-economic development.

In conclusion, edge computing technology not only drives the efficient operation and green transformation of energy systems but also plays a significant role in social sustainability, industrial economic upgrading, and climate change adaptation. By enhancing energy efficiency, reducing carbon emissions, and improving system consistency, edge computing provides crucial technological support for achieving SDGs. As a key enabler of digital transformation, edge computing's application in energy systems is becoming one of the core drivers of global progress toward sustainability.

4. IMPACT OF EDGE COMPUTING ON SOCIO-ECONOMIC DEVELOPMENT

With the acceleration of global digital transformation, the impact of edge computing on socio-economic development is becoming increasingly apparent, especially in areas such as industrial restructuring, labor market changes, capital flow, job innovation, and economic quality growth. Through various data processing, real-time decision support, and low-latency response, edge computing is driving socio-economic development towards more intelligent, green, and high-speed directions.

Firstly, the widespread adoption of edge computing has facilitated deep adjustments and transformation in industrial structures. Traditional industries, under the pressure of digital transformation, have leveraged edge computing, particularly in areas like energy management, smart manufacturing, and logistics, to achieve efficient resource allocation and refined management. Unlike centralized computing architectures, edge computing deploys computing and storage functions at the network edge, reducing latency, enhancing system reliability and flexibility, and promoting automation. (Wang, Jiye et al., 2015) This technology has accelerated the growth of emerging sectors such as the energy internet, smart grids, and industrial IoT, while fostering the clustering effect of related industries such as smart hardware, cloud computing, big data, and artificial intelligence, thus providing technological support for the optimization and upgrading of the global industrial landscape.

Secondly, the impact of edge computing on the labor market is dual-sided. As automation increases, the application of edge computing in production, operations, and decision-making processes may lead to the displacement of low-skill jobs, creating structural unemployment risks.(Zhang, Hong, 2019) However, it also generates strong demand for high-skill talent, especially in fields like data science, artificial intelligence, big data analysis, cybersecurity, and systems engineering, creating a need for cross-disciplinary expertise and advanced technical knowledge. Addressing this demand requires adjustments in education systems and vocational training, as well as new talent cultivation models to cope with changing technological needs and labor market challenges. Additionally, edge computing plays a vital role in promoting emerging industries and innovation-driven companies. In sectors such as smart cities, digital health, and intelligent logistics, edge computing is not only creating new job opportunities but also fostering the rapid development of tech-driven enterprises, enhancing both labor market vitality and social innovation capabilities. (Li, Qingsheng et al., 2019)

In the capital sector, edge computing has become a key technology in driving industrial digital transformation, gaining significant attention in the capital markets. Capital flows are shifting from traditional sectors like energy and infrastructure to digital technologies and green, sustainable development fields. As interest in smart hardware, IoT devices, big data analytics, and cloud computing rises, capital markets are supporting the commercialization of edge computing, accelerating technological development and marketization. By focusing on applications in energy, transportation, healthcare, education, and other sectors, the growing value of data as a core element of the digital economy is enhancing capital flow and accelerating technological innovation. (Wang, C. F. et al., 2017) This capital aggregation effect is providing a larger market environment for technology-driven companies, creating new ventures based on edge computing and driving economic growth.

Lastly, the application of edge computing significantly enhances socio-economic efficiency and drives the development of a green low-carbon economy. Against the backdrop of global energy transformation and sustainability goals, edge computing plays a crucial role in optimizing energy management, facilitating load scheduling, and improving energy efficiency. It reduces energy consumption, cuts environmental pollution, and enhances energy utilization. Through real-time data monitoring and optimization, edge computing helps industries improve energy efficiency and reduce carbon emissions, thus accelerating the transition to a green economy and sustainable development. (Wang, Jiye et al., 2015) Furthermore, edge computing's impact on transforming global economic growth models is profound, providing precise real-time decision-making and resource allocation mechanisms. This enhances the flexibility and adaptability of global supply chains, helping businesses respond to changing market demands and environmental uncertainties, while improving the quality and sustainability of economic growth.

5. CONCLUSION

This study explores the application of edge computing technology in energy systems, focusing on its key role in smart optimization and achieving sustainable development goals. Through a systematic analysis of its core applications in energy management, contributions to sustainable development, and socio-economic impacts, this research reveals the significant potential of edge computing in promoting green and low-carbon transformation, optimizing energy efficiency, and enhancing system economic responsiveness. The study shows that edge computing can improve the real-time and accuracy of energy management, playing a critical role in the widespread application of smart grids, energy management, and load scheduling. Additionally, edge computing drives the digital transformation of industries, promotes green economic development, optimizes industrial structure, and enhances social efficiency. The research also emphasizes the effective technical support and practical guidance edge computing provides in addressing climate change and achieving sustainable development goals.

Theoretically, this study deepens the understanding of edge computing, particularly its application models in energy systems and its relationship with sustainable development goals, filling a gap in the research. The findings offer theoretical references and strategic insights for governments and enterprises in developing energy internet strategies and promoting energy management technology innovation. Future research can further explore the integration of edge computing with other intelligent technologies like AI, IoT, and 5G, evaluating their combined effectiveness in different energy systems. Additionally, considering regional, policy, market, and technical differences in edge computing, future studies should focus on their differential impacts.

In conclusion, edge computing is a key technology for driving intelligent optimization in energy systems and achieving sustainable development goals, with significant application prospects and socio-economic importance. This research not only provides new perspectives for the field but also offers theoretical support for future technological innovation and policy development.

ACKNOWLEDGEMENT

Thanks to the National innovation and entrepreneurship training program for college students+S202410497347X, Leader in research, development and manufacturing of edge computing devices for energy Internet.

REFERENCE

[1] Shi, Wei Song, Zhang, Xingzhu, Wang, Yifan, et al. "Edge Computing: Current Status and Outlook." Computer Research and Development, vol. 56, no. 1, 2019, pp. 69-89.

[2] Edge Computing Industry Alliance, Industrial Internet Industry Alliance. Edge Computing Reference Architecture 2.0. Industrial Internet Industry Alliance, 2017.

[3] Sun, Yi, Fan, Lingjun, Hong, Xuehai. "Development and Application of Blockchain Technology: Status and Challenges." China Engineering Science, vol. 20, no. 2, 2018, pp. 27-32.

[4] He, Zhengyuan, Duan, Tiantian, Zhang, Ying, et al. "Application and Challenges of Blockchain Technology in the Internet of Things." Journal of Applied Science, vol. 38, no. 1, 2020, pp. 22-33.

[5] Wang, Tonghe, Hua, Haochen, Cao, Junwei. "Consensus Edge Computing and Its Application in the Energy Internet." Tsinghua University, 1. Beijing: Tsinghua University Automation Department, 100084, 2. Hohai University, Nanjing, 210098, 3. National Research Center for Information Science and Technology, Beijing, 100084.

[6] Wang, Jiye, Meng, Kun, Cao, Junwei, et al. "Research on Information Technology for Energy Internet." Computer Research and Development, vol. 52, no. 5, 2015, pp. 1109-1126.

[7] Wang, C. F., Cao, J., Li, F. "Space Energy Internet System." Proceedings of the 4th International Conference on Information Science and Control Engineering (ICISCE), IEEE, 2017, pp. 1713-1716.

[8] Wang, Jiye, Guo, Jinghong, Cao, Junwei, et al. "Review on Information and Communication Key Technologies of Energy Internet." Smart Grid, vol. 3, no. 6, 2015, pp. 473-485.

[9] Li, Qingsheng, Tang, Xueyong, Zhao, Qingming, et al. "Analysis of Applying Weak-Centralized Blockchain Technology in the Energy Trading System of Energy Internet." Power Systems and Big Data, vol. 22, no. 6, 2019, pp. 22-27.

[10] Zhang, Hong. Design and Implementation of Internet of Things Management System Based on Blockchain. University of Chinese Academy of Sciences, 2019.