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Digital Transformation and Energy Efficiency of Vietnamese Enterprises: Implications for Sustainable Development and Green Growth

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A B S T R A C T

Digital transformation has emerged as a critical driver of enterprise modernization and sustainable economic development in the digital era. This study examines the relationship between digital transformation and energy efficiency among Vietnamese enterprises and explores its implications for green growth and sustainable development. The study employs a quantitative research approach combined with secondary data analysis using information collected from national and international sources, including the General Statistics Office of Vietnam, the Ministry of Industry and Trade, the Ministry of Information and Communications, the World Bank, the International Energy Agency, OECD, and UNDP during the period 2015–2025. The findings indicate that digital transformation significantly contributes to improving energy efficiency through several mechanisms, including smart energy management, process automation, predictive maintenance, and data-driven decision-making. These digital solutions enable enterprises to optimize resource utilization, reduce energy waste, improve productivity, and strengthen operational performance. The study also confirms the relevance of the Resource-Based View, Technology Acceptance Theory, and Green Growth Theory in explaining the relationship between digital transformation and sustainable business development. The findings provide important implications for policymakers and enterprises seeking to accelerate digital transformation, improve energy efficiency, and support Vietnam's transition toward a sustainable and low-carbon economy

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INTRODUCTION

Digital transformation has become a major driver of economic growth and industrial modernization in the twenty-first century. The rapid advancement of technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, and smart manufacturing has fundamentally transformed business models, production processes, and management practices. Across both developed and developing economies, digital transformation is increasingly recognized as a strategic tool for improving productivity, reducing costs, enhancing competitiveness, and supporting sustainable development through resource optimization and low-carbon growth. At the same time, improving energy efficiency has become a critical challenge for enterprises worldwide. Industrial production, transportation, logistics, and commercial activities account for a significant share of global energy consumption and greenhouse gas emissions. Rising energy costs, environmental concerns, and stricter regulations have increased pressure on businesses to reduce energy use while maintaining productivity and profitability. As a result, energy efficiency has emerged as a strategic priority for enterprises seeking to balance economic performance with environmental responsibility. In recent years, growing attention has been devoted to the relationship between digital transformation and energy efficiency. Digital technologies enable real-time monitoring of energy consumption, predictive maintenance, automated production control, and data-driven decision-making. These capabilities help enterprises optimize resource utilization, reduce energy waste, and improve operational performance. Smart manufacturing systems and IoT-based energy management solutions, for example, can significantly lower energy consumption and carbon emissions while enhancing productivity.

The importance of this relationship is particularly evident in the context of sustainable development and green growth. Sustainable development emphasizes the balance between economic growth, social progress, and environmental protection, while green growth focuses on resource efficiency, technological innovation, and environmental sustainability. Digital transformation can contribute to these objectives by promoting cleaner production processes, improving resource productivity, and facilitating the transition toward a low-carbon economy. For Vietnam, digital transformation has become a national strategic priority. Through the National Digital Transformation Program and related policies, the government has encouraged enterprises to adopt advanced technologies and integrate digital solutions into production and management activities. Consequently, digital adoption has expanded across sectors such as manufacturing, finance, logistics, and telecommunications. Despite this progress, energy efficiency remains a major challenge for many Vietnamese enterprises. Numerous firms, particularly small and medium-sized enterprises (SMEs), continue to rely on outdated technologies, energy-intensive production processes, and inefficient resource management practices. Financial constraints, limited technological capabilities, and shortages of skilled human resources further restrict the adoption of advanced digital and energy-saving solutions. These challenges not only reduce

business competitiveness but also hinder national efforts toward sustainable development. The need to improve energy efficiency has become more urgent following Vietnam's commitment to achieving net-zero greenhouse gas emissions by 2050, announced at COP26. Meeting this target requires substantial improvements in energy efficiency across all sectors of the economy. In this context, digital transformation is increasingly viewed as a key mechanism for supporting a greener and more sustainable development model. However, the extent to which digital transformation contributes to energy efficiency among Vietnamese enterprises remains insufficiently understood.

Although previous studies have extensively examined digital transformation and enterprise performance, most focus on productivity, innovation, operational efficiency, and competitive advantage. Other studies investigate energy efficiency and environmental sustainability separately. Relatively few studies have systematically explored the relationship between digital transformation and energy efficiency, particularly in developing economies. In Vietnam, empirical evidence on how digital technologies influence enterprise-level energy efficiency remains limited, and existing research rarely integrates the broader perspectives of sustainable development and green growth. This research gap highlights the need for a comprehensive analysis of the role of digital transformation in improving energy efficiency among Vietnamese enterprises. Understanding this relationship is important not only for enhancing business competitiveness but also for supporting national goals related to green growth, climate change mitigation, and sustainable development. Against this background, this study aims to examine the impact of digital transformation on the energy efficiency of Vietnamese enterprises and explore its implications for sustainable development and green growth. Specifically, the study addresses three research questions: (1) What is the current status of digital transformation and energy efficiency among Vietnamese enterprises? (2) Through what mechanisms does digital transformation influence energy efficiency? and (3) What policy measures can strengthen the integration of digital transformation, energy efficiency, and sustainable development in Vietnam? By addressing these questions, the study contributes to the growing literature on sustainable business development and provides practical insights for enterprises and policymakers pursuing Vietnam's long-term development objectives.

LITERATURE REVIEW

Concept of Digital Transformation

Digital transformation has become one of the most influential trends shaping contemporary business and economic development. Although the concept has been widely discussed in both academic and practical contexts, there is no universally accepted definition due to its multidimensional nature. In general, digital transformation refers to the process through which organizations integrate digital technologies into their business activities, operational processes, management systems, and strategic decision-making in order to improve efficiency, create value, and enhance competitiveness. Unlike simple digitization,

which involves converting analog information into digital formats, digital transformation represents a broader organizational change that fundamentally alters the way firms operate, interact with stakeholders, and create economic value. The process of digital transformation is often described as occurring at different levels of maturity. At the basic level, enterprises focus on digitizing information and administrative procedures. The intermediate level involves the integration of digital technologies into production, logistics, and business management processes. At the advanced level, digital transformation becomes a strategic capability that reshapes business models, enables innovation, and supports sustainable growth. Therefore, digital transformation is not merely a technological phenomenon but also an organizational and managerial transformation that requires changes in corporate culture, human resources, and strategic orientation.

Several digital technologies serve as key enablers of digital transformation. Artificial Intelligence (AI) enables enterprises to automate decision-making processes, optimize production schedules, predict equipment failures, and improve resource allocation. Through machine learning algorithms and predictive analytics, AI contributes to greater operational efficiency while reducing unnecessary energy consumption. Big Data analytics allows organizations to collect, process, and analyze vast amounts of information generated from production systems, customers, and supply chains. The ability to transform raw data into actionable insights helps enterprises identify inefficiencies, improve productivity, and support evidence-based decision-making. The Internet of Things (IoT) plays a crucial role in connecting physical assets, machines, and devices through digital networks. IoT technologies enable real-time monitoring of production processes, energy consumption, and equipment performance. As a result, enterprises can detect abnormalities, reduce energy waste, and improve operational control. Similarly, Cloud Computing provides scalable and flexible digital infrastructure that supports data storage, information sharing, and collaborative operations across organizational units. By reducing the need for extensive physical infrastructure and facilitating digital integration, cloud computing contributes to both operational efficiency and resource optimization. Another important dimension of digital transformation is Smart Manufacturing, which represents the integration of advanced digital technologies into industrial production systems. Smart manufacturing combines AI, IoT, robotics, and data analytics to create intelligent production environments capable of self-monitoring, self-adjustment, and continuous optimization. Such systems improve productivity, reduce operational costs, and enhance energy efficiency by minimizing resource waste and maximizing process performance. Consequently, digital transformation has become a strategic instrument for enterprises seeking to improve both economic and environmental outcomes.

Concept of Energy Efficiency

Energy efficiency is widely recognized as a fundamental component of sustainable economic development and environmental protection. In general, energy efficiency refers to the ability to produce a given level of output while consuming less energy input. It reflects the extent to which energy resources are

utilized effectively in production, transportation, and service activities. Improving energy efficiency enables enterprises to reduce operational costs, increase productivity, enhance competitiveness, and minimize environmental impacts associated with energy consumption. From an economic perspective, energy efficiency is often viewed as a measure of how effectively enterprises convert energy resources into economic value. Higher energy efficiency indicates that fewer energy resources are required to produce the same quantity of goods or services. Consequently, improvements in energy efficiency contribute to resource conservation, lower production costs, and greater economic sustainability.

Several indicators are commonly used to evaluate energy efficiency. One of the most widely applied measures is Energy Intensity, which refers to the amount of energy consumed per unit of economic output. Lower energy intensity indicates a higher level of energy efficiency because less energy is required to generate economic value. Energy intensity is frequently used at both enterprise and national levels to assess the relationship between economic growth and energy consumption. Another important indicator is Energy Productivity, which measures the amount of economic output generated per unit of energy consumed. Unlike energy intensity, higher energy productivity reflects better energy performance because enterprises are able to create more value from the same amount of energy input. Energy productivity is increasingly used as an indicator of sustainable growth and resource efficiency. In addition, Energy Consumption per Unit of Output is commonly employed to assess operational efficiency within specific industries and production processes. This indicator measures the quantity of energy required to produce a particular unit of product or service. Reductions in energy consumption per unit of output are generally interpreted as evidence of technological improvement, operational optimization, and enhanced resource management. Together, these indicators provide valuable insights into the effectiveness of energy utilization and the sustainability of enterprise operations.

Sustainable Development and Green Growth

The concept of sustainable development emerged from growing concerns regarding the environmental and social consequences of economic growth. The most widely cited definition was introduced by the World Commission on Environment and Development, which defined sustainable development as development that meets present needs without compromising the ability of future generations to meet their own needs. This perspective emphasizes the need to balance economic prosperity, social well-being, and environmental sustainability. In recent years, the concept of green growth has gained increasing prominence as a complementary approach to sustainable development. Green growth refers to a development strategy that promotes economic expansion while ensuring the efficient use of natural resources, reducing environmental degradation, and enhancing ecological resilience. Rather than viewing environmental protection as a constraint on economic growth, green growth emphasizes the potential for technological innovation and resource efficiency to generate both economic and environmental benefits.

The relationship between economic growth and environmental protection has long been debated in economic and environmental literature. Traditional development models often assume a trade-off between economic expansion and environmental sustainability. However, contemporary perspectives increasingly argue that technological innovation can help reconcile these objectives. Through improvements in energy efficiency, resource productivity, and environmental performance, technological advancement enables enterprises to achieve economic growth while reducing ecological impacts. Consequently, digital transformation has emerged as a key mechanism for supporting green growth and sustainable development in the modern economy.

Theoretical Foundations

Resource-Based View (RBV)

The Resource-Based View (RBV) provides an important theoretical foundation for understanding the strategic role of digital transformation within enterprises. According to RBV, sustainable competitive advantage arises from valuable, rare, inimitable, and non-substitutable resources possessed by firms. In the contemporary business environment, digital technologies increasingly satisfy these criteria because they enhance organizational capabilities, facilitate innovation, and improve operational performance. From the RBV perspective, digital transformation should not be viewed merely as the adoption of technology but rather as the development of strategic organizational capabilities. Enterprises that effectively integrate digital technologies into their operations can optimize resource utilization, improve energy management, and achieve superior performance compared to competitors. Therefore, digital transformation represents a strategic resource that contributes to both economic competitiveness and sustainable development.

Technology Acceptance Theory

Technology Acceptance Theory explains how individuals and organizations adopt and utilize new technologies. The theory suggests that technology adoption is influenced primarily by perceived usefulness and perceived ease of use. Within enterprises, the successful implementation of digital technologies depends on managerial support, employee readiness, technological competence, and organizational culture. In the context of digital transformation, enterprises are more likely to adopt digital technologies when they perceive clear economic and operational benefits. Technologies that improve productivity, reduce costs, and enhance energy efficiency are generally associated with higher acceptance levels. Consequently, Technology Acceptance Theory provides a useful framework for understanding the conditions that facilitate digital transformation and its contribution to organizational performance.

Green Growth Theory

Green Growth Theory emphasizes the role of technological innovation in promoting sustainable economic development. The theory argues that environmental sustainability and economic growth are not mutually exclusive objectives but can reinforce one another through innovation, resource efficiency, and structural transformation. Technological advancement enables enterprises to reduce energy consumption, lower carbon emissions, and improve

environmental performance while maintaining economic competitiveness. Within this framework, digital transformation functions as an important driver of green growth because it facilitates operational optimization, intelligent resource management, and energy-efficient production systems. By improving energy efficiency and reducing environmental impacts, digital technologies contribute to the achievement of sustainable development goals and long-term economic resilience.

Empirical Studies

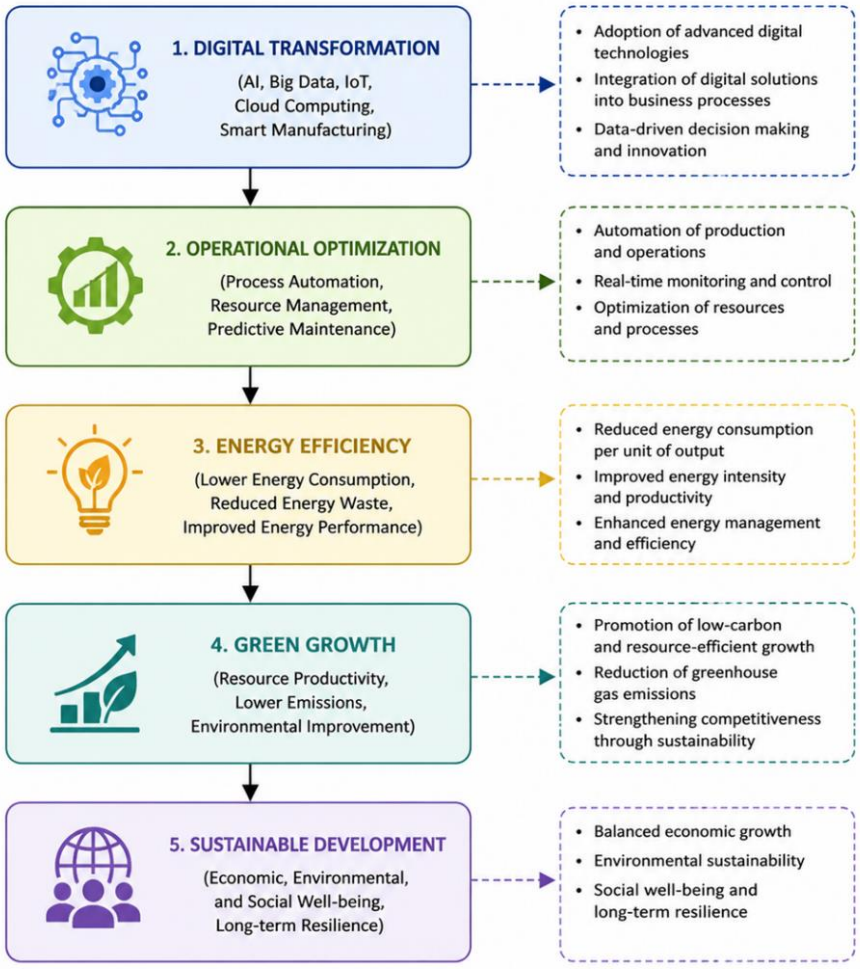
A growing body of international literature has examined the relationship between digital transformation, energy efficiency, and sustainable development. Studies conducted in developed economies generally indicate that digital technologies contribute significantly to energy savings, operational optimization, and environmental performance. Research on Industry 4.0 technologies suggests that AI, IoT, and smart manufacturing systems enable enterprises to improve resource utilization while reducing energy consumption and carbon emissions. In ASEAN countries, digital transformation has increasingly been recognized as a strategic instrument for enhancing industrial competitiveness and promoting sustainable growth. Empirical studies from Singapore, Malaysia, Thailand, and Indonesia indicate that digital technologies improve production efficiency, support energy management systems, and strengthen environmental sustainability. Nevertheless, the magnitude of these benefits varies depending on technological readiness, institutional quality, and organizational capabilities. In Vietnam, research on digital transformation has expanded rapidly during the past decade. Existing studies primarily focus on digital adoption, enterprise performance, innovation capacity, and business competitiveness. Meanwhile, research on energy efficiency has largely examined industrial energy consumption, energy-saving technologies, and environmental sustainability. Despite these advances, limited attention has been devoted to examining the direct relationship between digital transformation and energy efficiency at the enterprise level. Moreover, few studies have integrated the broader perspectives of sustainable development and green growth into the analysis.

Conceptual Framework

Based on the theoretical foundations and empirical studies reviewed above, this study proposes a conceptual framework that explains the relationship between digital transformation, energy efficiency, green growth, and sustainable development within the context of Vietnamese enterprises. The framework is grounded in the Resource-Based View (RBV), Technology Acceptance Theory, and Green Growth Theory. These theoretical perspectives collectively suggest that digital technologies function as strategic organizational resources that enhance operational capabilities, improve resource utilization, and support sustainable business performance. The framework assumes that digital transformation serves as the primary driver of operational optimization through the adoption of advanced technologies such as Artificial Intelligence (AI), Big Data Analytics, the Internet of Things (IoT), Cloud Computing, and Smart Manufacturing systems. The integration of these technologies enables enterprises to automate production processes, monitor energy consumption in real time,

optimize resource allocation, and improve decision-making quality. As operational efficiency increases, enterprises are able to reduce energy waste and improve overall energy performance. Improved energy efficiency subsequently contributes to green growth by promoting resource productivity, lowering carbon emissions, and reducing environmental impacts. Ultimately, these outcomes support broader sustainable development objectives by generating economic benefits, enhancing environmental sustainability, and strengthening long-term business resilience.

Figure 1. Conceptual Framework of the Study



Source: Developed by the author based on Resource-Based View (RBV), Technology Acceptance Theory, and Green Growth Theory.

As illustrated in Figure 1, digital transformation influences sustainable development indirectly through a sequential mechanism. The adoption of digital technologies enhances operational optimization, which in turn improves energy efficiency. Higher energy efficiency supports green growth by reducing resource consumption and environmental pressures while maintaining economic productivity. Through this pathway, digital transformation contributes not only to enterprise competitiveness but also to broader national goals related to sustainable development and the transition toward a low-carbon economy.

METHODOLOGY

Research Approach

This study employs a quantitative research approach combined with secondary data analysis to examine the relationship between digital transformation and energy efficiency among Vietnamese enterprises and to explore its implications for sustainable development and green growth. The quantitative approach is considered appropriate because it enables the systematic analysis of measurable indicators related to digital adoption, energy utilization, and sustainable development performance. Furthermore, the use of secondary data allows for the examination of long-term trends and broader economic patterns at the national and enterprise levels. In addition to quantitative analysis, the study incorporates a comprehensive review of policy documents, statistical reports, and previous academic studies. This approach facilitates a deeper understanding of the mechanisms through which digital transformation influences operational optimization, energy efficiency, and sustainability outcomes. By integrating quantitative evidence with contextual analysis, the study seeks to provide a comprehensive assessment of the role of digital transformation in promoting energy-efficient and sustainable business development in Vietnam. The research adopts an exploratory and explanatory design. The exploratory dimension aims to identify major trends and patterns regarding digital transformation and energy efficiency, while the explanatory dimension seeks to investigate the potential relationships among the selected variables. Given the availability of secondary data and the broad scope of the study, the findings are interpreted primarily as indicative relationships rather than definitive causal effects.

Data Collection

The study relies exclusively on secondary data collected from national and international sources. Data were obtained from official publications, statistical reports, policy documents, and databases produced by government agencies and international organizations. The primary domestic data sources include the General Statistics Office of Vietnam (GSO), the Ministry of Industry and Trade (MOIT), the Ministry of Science and Technology (MOST), and the Ministry of Information and Communications (MIC). These institutions provide information related to enterprise development, industrial production, technological innovation, digital transformation, energy consumption, and energy efficiency indicators. To ensure data reliability and international comparability, additional information was collected from several international organizations, including the World Bank, the International Energy Agency (IEA), the Organisation for Economic Co-operation and Development (OECD), and the United Nations Development Programme (UNDP). These sources provide comprehensive datasets on digital transformation, energy productivity, sustainable development, and green growth indicators.

The study covers the period from 2015 to 2025. This period was selected because it reflects the accelerated adoption of digital technologies in Vietnam and coincides with major policy initiatives related to digital transformation, energy efficiency improvement, green growth, and sustainable development. Data from

multiple sources were cross-checked and synthesized to improve consistency and accuracy. The collected information was subsequently organized into thematic categories corresponding to the study variables and analytical framework.

Research Variables

The conceptual framework of this study consists of several interconnected variables that explain the relationship between digital transformation and sustainable development outcomes. The independent variable is Digital Transformation, which refers to the adoption and integration of digital technologies into enterprise operations, management systems, and production processes. Indicators associated with digital transformation include digital technology adoption, information technology investment, digital infrastructure development, and the implementation of Industry 4.0 technologies. The dependent variable is Energy Efficiency, which reflects the effectiveness with which enterprises utilize energy resources to generate economic output. Energy efficiency is evaluated through indicators such as energy intensity, energy productivity, and energy consumption per unit of output. The study also includes Operational Optimization as a mediating variable. Operational optimization represents improvements in production efficiency, resource utilization, process automation, predictive maintenance, and data-driven management practices that arise from digital transformation. It serves as the mechanism through which digital technologies influence energy efficiency. Two outcome variables are incorporated into the conceptual framework: Green Growth and Sustainable Development Performance. Green growth refers to economic development achieved through resource efficiency, environmental sustainability, and reduced carbon emissions. Sustainable development performance reflects broader economic, environmental, and social outcomes associated with long-term sustainability. To improve analytical robustness, several control variables are considered, including Enterprise Size, Industry Type, and Investment Capital. These variables may influence both digital transformation and energy efficiency and are therefore included to provide a more comprehensive understanding of the observed relationships.

Analytical Methods

Several analytical techniques are employed to achieve the research objectives. First, descriptive statistical analysis is used to summarize major trends and characteristics of digital transformation, energy consumption, and energy efficiency in Vietnamese enterprises. Descriptive statistics provide an overview of the current situation and help identify important patterns within the data. Second, comparative analysis is applied to examine differences in digital transformation and energy efficiency across industries, enterprise sizes, and time periods. This method helps identify sectors that have demonstrated stronger progress in digital adoption and energy performance. Third, trend analysis is conducted to evaluate the evolution of digital transformation and energy efficiency indicators during the 2015–2025 period. Through trend analysis, the study assesses whether improvements in digital adoption are associated with changes in energy performance over time. Fourth, correlation analysis is employed to examine the degree of association between digital transformation

indicators and energy efficiency measures. Correlation coefficients provide preliminary evidence regarding the strength and direction of relationships among the variables.

Finally, simple regression analysis is utilized to estimate the impact of digital transformation on energy efficiency. The regression model is used to assess whether changes in digital transformation indicators are associated with improvements in energy efficiency while considering the influence of selected control variables. Given the exploratory nature of the study and the reliance on secondary data, the regression results are interpreted primarily as indicative relationships rather than definitive causal conclusions. The combination of descriptive statistics, comparative analysis, trend analysis, correlation analysis, and regression analysis provides a comprehensive methodological framework for examining how digital transformation contributes to energy efficiency and supports sustainable development and green growth in Vietnam.

RESULT

Current Status of Digital Transformation in Vietnamese Enterprises

Digital transformation has become one of the most significant trends shaping the development trajectory of Vietnamese enterprises during the past decade. Driven by rapid technological advancement, increasing global competition, and supportive government policies, enterprises across various sectors have gradually integrated digital technologies into their production, management, and business operations. The implementation of the National Digital Transformation Program and other related policy initiatives has created favorable conditions for enterprises to accelerate digital adoption and improve their competitiveness in both domestic and international markets. The level of digital transformation among Vietnamese enterprises has improved considerably in recent years. According to reports from government agencies and international organizations, an increasing number of firms have adopted digital solutions in areas such as enterprise resource planning (ERP), customer relationship management (CRM), e-commerce platforms, cloud computing, and data analytics. The COVID-19 pandemic further accelerated digital transformation by forcing businesses to adopt remote working systems, digital communication tools, and online business models. As a result, digital technologies have become an essential component of business resilience and operational continuity.

Despite this progress, the degree of digital transformation remains uneven across enterprises and industries. Large enterprises generally demonstrate higher levels of digital readiness due to greater financial resources, stronger technological capabilities, and better access to skilled human capital. In contrast, many small and medium-sized enterprises (SMEs) continue to face challenges related to limited investment capital, insufficient technological infrastructure, and shortages of qualified digital personnel. Consequently, the digital transformation process among Vietnamese enterprises remains characterized by significant disparities in technological adoption and implementation effectiveness. Several sectors have emerged as pioneers in digital transformation.

The banking and financial services sector has experienced substantial digitalization through the expansion of digital banking platforms, electronic payment systems, artificial intelligence applications, and data-driven customer services. Similarly, the telecommunications and information technology sectors have demonstrated strong digital capabilities and have played a leading role in providing digital infrastructure for other industries. Manufacturing enterprises, particularly those involved in export-oriented production, have increasingly adopted Industry 4.0 technologies such as automation systems, industrial IoT, robotics, and smart manufacturing solutions to improve productivity and operational efficiency. The logistics and transportation sector has also accelerated digital adoption through the implementation of digital supply chain management systems, warehouse automation technologies, and real-time tracking platforms. These technologies enable enterprises to optimize transportation routes, reduce operational costs, and improve resource utilization. In addition, the retail sector has witnessed significant growth in e-commerce, digital marketing, and data analytics applications, reflecting the increasing importance of digital technologies in enhancing customer engagement and business performance.

One notable trend in recent years is the growing investment in advanced digital technologies. Vietnamese enterprises are increasingly allocating resources toward artificial intelligence, big data analytics, cloud computing, and Internet of Things (IoT) applications. These technologies are no longer viewed merely as tools for improving productivity but are increasingly regarded as strategic assets that support innovation, competitiveness, and long-term sustainability. In particular, cloud-based solutions have become attractive due to their flexibility, scalability, and relatively low implementation costs, making them accessible to a wider range of enterprises. The adoption of artificial intelligence and big data analytics has also expanded significantly. Enterprises are utilizing these technologies to improve forecasting accuracy, optimize production planning, enhance customer service, and support managerial decision-making. Furthermore, IoT technologies are increasingly used in industrial production environments to monitor equipment performance, track energy consumption, and facilitate predictive maintenance. Such applications contribute not only to operational efficiency but also to resource conservation and environmental sustainability. Government support has played an important role in encouraging digital transformation investment. Various policy programs have been introduced to promote technological innovation, digital infrastructure development, and enterprise digitalization. Financial incentives, technology support initiatives, and digital capacity-building programs have helped create a more favorable environment for technology adoption. Nevertheless, challenges remain regarding digital skills development, cybersecurity concerns, and the financial burden associated with technological upgrading, particularly for SMEs.

Overall, the current status of digital transformation in Vietnamese enterprises reflects a dynamic but uneven process of technological modernization. While significant progress has been achieved in digital adoption, substantial differences continue to exist across sectors and enterprise sizes. The

increasing investment in digital technologies, combined with supportive government policies and growing market demand for innovation, indicates that digital transformation will continue to play a central role in shaping the future development of Vietnamese enterprises. More importantly, the expanding application of digital technologies provides a critical foundation for improving operational optimization, enhancing energy efficiency, and supporting broader objectives related to green growth and sustainable development.

Current Status of Energy Consumption and Energy Efficiency

Energy consumption has become an increasingly important issue in Vietnam's economic development process. As one of the fastest-growing economies in Southeast Asia, Vietnam has experienced rapid industrialization, urbanization, and expansion of manufacturing activities over the past two decades. While these developments have contributed significantly to economic growth and export performance, they have also resulted in a substantial increase in energy demand. According to national energy reports and international assessments, Vietnam's total energy consumption has grown considerably faster than the global average, reflecting the country's increasing reliance on industrial production, transportation, and commercial activities. Consequently, improving energy efficiency has become a strategic priority for ensuring sustainable economic growth and enhancing national energy security. The industrial sector remains the largest energy-consuming sector in Vietnam. Manufacturing industries such as steel, cement, textiles, electronics, chemicals, and food processing account for a significant share of total industrial energy demand. Among these industries, steel and cement production are particularly energy-intensive due to their heavy reliance on thermal energy and continuous production processes. Similarly, textile and garment enterprises consume large amounts of electricity for machinery operation, air-conditioning systems, and production activities. As Vietnam continues to strengthen its position within global supply chains, industrial energy consumption is expected to remain high in the coming years.

In addition to manufacturing, the transportation and logistics sector represents another major source of energy consumption. The rapid growth of e-commerce, urban mobility, and international trade has increased demand for freight transportation, warehousing, and distribution services. These activities require substantial energy inputs in the form of fuel consumption, electricity use, and logistics infrastructure operations. Meanwhile, the commercial and service sectors have also witnessed rising energy demand due to the expansion of office buildings, shopping centers, hospitality services, and digital infrastructure facilities. Collectively, these trends illustrate the growing importance of energy management across multiple sectors of the Vietnamese economy. Despite increasing awareness of energy conservation, the overall level of energy efficiency in many Vietnamese enterprises remains relatively modest compared with international standards. Various studies have shown that energy intensity in several industrial sectors remains higher than that of many developed economies and some regional competitors. This indicates that a considerable amount of energy is still required to generate a given level of economic output.

Although improvements have been recorded in certain industries through technological upgrading and energy-saving initiatives, the pace of progress remains uneven across sectors and enterprise categories. Energy productivity, which measures the amount of economic value generated per unit of energy consumed, has gradually improved in recent years. This improvement reflects ongoing efforts to modernize production systems, adopt cleaner technologies, and enhance resource management practices. However, energy productivity growth remains constrained by structural factors such as outdated production technologies, inefficient equipment, and limited investment in energy-efficient systems. Consequently, many enterprises continue to face challenges in achieving substantial reductions in energy consumption while maintaining production growth.

Another commonly used indicator, energy consumption per unit of output, reveals considerable differences among industries. Enterprises that have invested in modern technologies and automated production systems generally demonstrate lower energy consumption per unit of output than firms relying on conventional production methods. This suggests that technological innovation and operational optimization play a critical role in improving energy performance. Nevertheless, a large proportion of small and medium-sized enterprises continue to operate with aging machinery and inefficient production processes, resulting in higher energy consumption and lower overall productivity. Several limitations continue to hinder improvements in energy efficiency among Vietnamese enterprises. One of the most significant challenges is the widespread use of outdated technologies and equipment. Many enterprises, particularly SMEs, lack the financial resources necessary to replace obsolete machinery with modern energy-efficient alternatives. As a result, energy losses during production remain relatively high, reducing both economic efficiency and environmental performance. Another important limitation relates to the lack of advanced energy management systems. In many enterprises, energy consumption is still monitored manually or through fragmented management practices. The absence of real-time monitoring systems, predictive analytics, and automated control mechanisms limits the ability of firms to identify inefficiencies and implement timely corrective measures. Consequently, opportunities for energy savings often remain unrealized.

Human resource constraints also represent a significant barrier. Many enterprises lack personnel with specialized expertise in energy management, digital technologies, and sustainability practices. Without adequate technical knowledge and managerial capacity, firms may encounter difficulties in implementing energy-saving measures and integrating innovative technologies into their operations. Furthermore, awareness of energy efficiency as a strategic business objective remains limited among some enterprise managers, particularly in traditional industries. Financial constraints constitute another major obstacle. Although investments in energy-efficient technologies often generate long-term economic benefits, the initial costs associated with technology acquisition, system integration, and workforce training can be substantial. For many SMEs, limited access to financial resources and green financing

mechanisms restricts their ability to undertake such investments. This challenge is further compounded by uncertainties regarding investment returns and technological performance. Overall, the current status of energy consumption and energy efficiency in Vietnamese enterprises reveals both progress and persistent challenges. While energy productivity has improved and awareness of sustainable production has increased, significant inefficiencies remain across many sectors. High energy consumption, technological limitations, insufficient energy management practices, and financial constraints continue to hinder progress toward greater resource efficiency. These findings suggest that further improvements in energy performance will require not only technological upgrading but also more effective management practices and broader adoption of digital technologies. In this regard, digital transformation may provide an important pathway for addressing existing inefficiencies and enhancing energy efficiency in Vietnamese enterprises, a relationship that is examined in the following section.

Impact of Digital Transformation on Energy Efficiency

Smart Energy Management

One of the most important contributions of digital transformation to energy efficiency is the development of smart energy management systems. Traditionally, energy consumption in many enterprises has been monitored through periodic inspections and manual reporting procedures. Such approaches often provide limited information regarding real-time energy usage and make it difficult to identify inefficiencies or abnormal consumption patterns. As a result, significant opportunities for energy conservation frequently remain undetected. The integration of digital technologies, particularly IoT devices, sensors, cloud-based platforms, and advanced monitoring software, has fundamentally transformed energy management practices. These technologies enable enterprises to collect and analyze energy consumption data continuously across production facilities, machinery, and operational units. Through real-time monitoring systems, managers can obtain accurate information regarding electricity usage, equipment performance, production efficiency, and energy loss sources.

The availability of real-time data significantly improves energy management effectiveness. Enterprises can immediately identify excessive energy consumption, equipment malfunctions, and inefficient operational practices. Moreover, digital dashboards and automated reporting systems allow managers to evaluate energy performance more accurately and implement corrective actions in a timely manner. Such capabilities contribute to substantial reductions in unnecessary energy consumption while maintaining production efficiency. In addition, smart energy management systems facilitate the establishment of energy-saving targets and performance benchmarks. Continuous monitoring enables enterprises to evaluate progress toward sustainability objectives and support compliance with environmental regulations. Consequently, smart energy management has emerged as a key component of enterprise strategies aimed at improving both economic and environmental performance.

Process Automation

Another important mechanism through which digital transformation improves energy efficiency is process automation. Automation technologies have become increasingly common in modern manufacturing environments, particularly among enterprises implementing Industry 4.0 strategies. By integrating robotics, automated control systems, artificial intelligence, and intelligent manufacturing technologies, firms can reduce human intervention and optimize production activities. Process automation enhances energy efficiency by minimizing operational errors and reducing resource waste. Automated systems are capable of maintaining optimal production conditions, adjusting machine settings, and coordinating production schedules more accurately than traditional manual operations. This precision reduces energy losses associated with production interruptions, equipment idling, and inefficient resource allocation. Furthermore, automation enables enterprises to synchronize production activities with actual demand conditions. Smart production systems can dynamically adjust operational parameters according to workload requirements, thereby preventing excessive energy consumption during periods of low utilization. Such flexibility contributes to more efficient use of energy resources while maintaining productivity and product quality.

The benefits of automation are particularly evident in energy-intensive industries such as manufacturing, steel production, cement production, and electronics assembly. In these sectors, automated production systems contribute to lower energy consumption per unit of output and improved operational efficiency. Consequently, process automation not only supports productivity growth but also strengthens enterprise efforts toward sustainable production and environmental responsibility.

Predictive Maintenance

Predictive maintenance represents another significant pathway through which digital transformation enhances energy efficiency. In conventional maintenance systems, equipment servicing is typically conducted either according to fixed schedules or after mechanical failures occur. Both approaches often result in inefficiencies. Scheduled maintenance may lead to unnecessary servicing activities, while reactive maintenance can cause unexpected equipment breakdowns, production disruptions, and excessive energy consumption. Digital technologies provide a more advanced alternative through predictive maintenance systems. By utilizing sensors, IoT devices, machine learning algorithms, and data analytics, enterprises can continuously monitor equipment conditions and predict potential failures before they occur. These systems analyze operational data such as temperature, vibration, pressure, and energy consumption patterns to identify early signs of equipment deterioration. The implementation of predictive maintenance contributes to energy efficiency in several ways. First, properly functioning equipment generally consumes less energy than malfunctioning or poorly maintained machinery. Second, predictive maintenance reduces downtime and prevents sudden production interruptions that often result in inefficient energy usage. Third, early detection of equipment abnormalities enables enterprises to implement corrective actions before energy losses become substantial.In addition to improving energy performance,

predictive maintenance generates broader operational benefits, including reduced maintenance costs, extended equipment lifespan, and improved production reliability. These advantages strengthen the economic rationale for investing in digital technologies and support the transition toward more sustainable industrial operations.

Data-Driven Decision Making

The ability to collect, process, and analyze large volumes of data represents one of the most transformative aspects of digital transformation. Data-driven decision-making enables enterprises to move beyond intuition-based management and adopt evidence-based strategies for improving operational performance and energy efficiency. Big data analytics plays a central role in this process. Modern enterprises generate substantial amounts of information from production systems, supply chains, customer interactions, and energy management platforms. Through advanced analytical tools, organizations can transform these data into actionable insights that support resource optimization and strategic planning. In the context of energy management, data analytics enables enterprises to identify patterns of energy consumption, evaluate operational performance, and forecast future energy requirements. Analytical models can reveal hidden inefficiencies that may not be apparent through conventional management approaches. For example, enterprises can identify specific production stages that consume excessive energy, compare performance across facilities, and assess the effectiveness of energy-saving initiatives. Moreover, predictive analytics supports proactive energy management by forecasting demand fluctuations and optimizing resource allocation. Enterprises can adjust production schedules, manage peak-load periods, and improve operational planning based on data-driven insights. Such capabilities contribute to lower energy consumption, reduced operational costs, and enhanced sustainability performance. The increasing availability of digital data also facilitates more informed strategic decision-making regarding technology investments, production optimization, and sustainability initiatives. As enterprises gain greater visibility into their energy performance, they become better positioned to develop long-term strategies that balance economic growth with environmental responsibility. Therefore, data-driven decision-making represents a critical mechanism through which digital transformation supports both energy efficiency and sustainable business development.

Overall, the findings suggest that digital transformation improves energy efficiency through multiple complementary mechanisms. Smart energy management systems provide real-time visibility into energy consumption, process automation enhances operational precision, predictive maintenance reduces equipment-related inefficiencies, and data-driven decision-making supports strategic resource optimization. Together, these mechanisms create a comprehensive pathway through which digital technologies contribute to improved energy performance and sustainable enterprise development.

Impact on Green Growth and Sustainable Development

The findings indicate that the benefits of digital transformation extend beyond improvements in operational efficiency and energy management. By enhancing energy efficiency, digital technologies generate broader economic, environmental, and social impacts that contribute directly to green growth and sustainable development objectives. In the context of Vietnam's transition toward a digital economy and low-carbon development model, the integration of digital technologies into enterprise operations has emerged as an important mechanism for promoting resource efficiency and environmental sustainability. One of the most significant contributions of digital transformation is the reduction of carbon emissions. Improved energy efficiency enables enterprises to consume less energy while maintaining or increasing production output. Because a substantial proportion of Vietnam's energy supply is still derived from fossil fuels, lower energy consumption translates directly into reduced greenhouse gas emissions. Smart energy management systems, automated production processes, and predictive maintenance technologies help minimize energy waste and improve resource utilization, thereby lowering the carbon footprint of business activities. As enterprises increasingly adopt digital technologies, cumulative reductions in energy consumption can generate substantial environmental benefits at both sectoral and national levels.

Digital transformation also contributes to higher resource productivity, which is a central objective of green growth strategies. Resource productivity refers to the ability to generate greater economic value from a given quantity of resources. Through advanced data analytics, intelligent production systems, and digital monitoring platforms, enterprises can optimize the use of energy, raw materials, labor, and capital. This optimization reduces inefficiencies and supports more sustainable production patterns. As a result, enterprises are able to achieve higher output levels while utilizing fewer resources, thereby strengthening both economic performance and environmental sustainability. Another important outcome is the enhancement of enterprise competitiveness. In increasingly competitive global markets, firms are under growing pressure to improve efficiency, reduce production costs, and comply with environmental standards. Digital transformation provides enterprises with the technological capabilities needed to achieve these objectives simultaneously. Lower energy costs improve profitability, while enhanced environmental performance strengthens corporate reputation and facilitates access to international markets. This is particularly important for Vietnamese exporters, which are increasingly required to comply with sustainability standards, carbon reporting requirements, and environmental regulations imposed by international trading partners.

Furthermore, digital transformation supports innovation and organizational resilience. The adoption of digital technologies enables enterprises to respond more effectively to changing market conditions, technological disruptions, and environmental challenges. Firms that successfully integrate digital technologies into their operations are generally better positioned to adapt to emerging sustainability requirements and capitalize on new

opportunities associated with green economic development. Consequently, digital transformation not only improves current performance but also enhances long-term competitiveness and resilience. The contribution of digital transformation to sustainable development is also evident through its support for national policy objectives. Vietnam has committed to achieving net-zero greenhouse gas emissions by 2050 and has introduced numerous policies aimed at promoting green growth, sustainable development, and digital transformation. The findings suggest that digital technologies can serve as an important enabler of these objectives by improving energy efficiency, reducing environmental impacts, and fostering sustainable business practices. Therefore, digital transformation should be viewed not only as a technological strategy but also as a critical component of Vietnam's broader sustainable development agenda. Overall, the evidence suggests that digital transformation contributes to green growth and sustainable development through multiple pathways. By reducing carbon emissions, increasing resource productivity, enhancing competitiveness, and supporting environmental sustainability, digital technologies create substantial value for enterprises and society. These findings highlight the strategic importance of integrating digital transformation initiatives with energy efficiency and sustainability policies in order to achieve long-term economic and environmental objectives.

DISCUSSION

The findings of this study are generally consistent with previous international research emphasizing the positive relationship between digital transformation and energy efficiency. Numerous studies have argued that digital technologies facilitate resource optimization, operational efficiency, and sustainable production practices. Similar to findings reported in developed economies and several ASEAN countries, this study suggests that digital transformation contributes significantly to improved energy management through real-time monitoring, process automation, predictive maintenance, and data-driven decision-making. These results reinforce the growing consensus that digital technologies play an increasingly important role in promoting sustainable business development. The findings also support previous empirical studies indicating that Industry 4.0 technologies can generate both economic and environmental benefits. Earlier research has demonstrated that artificial intelligence, IoT systems, and big data analytics improve production efficiency while reducing resource consumption and carbon emissions. The evidence from Vietnamese enterprises suggests that similar mechanisms are emerging within the domestic business environment. Although the level of technological adoption varies across industries and enterprise sizes, the overall direction of the relationship remains consistent with international experience.

From the perspective of the Resource-Based View (RBV), the findings confirm that digital technologies function as strategic organizational resources capable of generating sustainable competitive advantage. Enterprises that effectively integrate digital technologies into their operational processes are able to improve resource utilization, reduce energy waste, and strengthen

productivity. These capabilities are difficult for competitors to replicate quickly because they require not only technological investments but also organizational learning, managerial expertise, and digital competencies. Consequently, digital transformation represents a valuable strategic asset that contributes simultaneously to economic performance and sustainability outcomes. The results can also be interpreted through the lens of Technology Acceptance Theory. The study suggests that the benefits of digital transformation depend not only on the availability of technology but also on the willingness and ability of enterprises to adopt and utilize digital solutions effectively. Enterprises that perceive digital technologies as useful and economically beneficial are more likely to invest in advanced systems and integrate them into their operations. Conversely, firms facing financial constraints, technological barriers, or limited digital capabilities often experience slower progress in digital transformation and energy efficiency improvement. This finding highlights the importance of organizational readiness and technological acceptance in determining the success of digital initiatives.

Furthermore, the findings provide strong support for Green Growth Theory. The theory argues that technological innovation serves as a key driver of sustainable economic development by improving resource efficiency and reducing environmental pressures. The results of this study demonstrate that digital transformation contributes to green growth through enhanced energy efficiency, lower carbon emissions, and improved resource productivity. Rather than creating a trade-off between economic growth and environmental protection, digital technologies enable enterprises to achieve both objectives simultaneously. This finding reinforces the view that technological innovation can play a central role in supporting the transition toward a low-carbon and resource-efficient economy. Despite these positive outcomes, the findings also reveal several challenges that may limit the effectiveness of digital transformation. Technological disparities among enterprises, insufficient digital skills, limited financial resources, and unequal access to advanced technologies continue to constrain progress. These challenges are particularly evident among SMEs, which often face greater barriers to technological adoption than large enterprises. Therefore, while digital transformation offers substantial opportunities for improving energy efficiency and sustainability, its success depends on supportive policies, institutional capacity, and continuous investment in technological development.

In summary, the findings demonstrate that digital transformation has become an important catalyst for improving energy efficiency and promoting sustainable development in Vietnam. The results not only confirm the relevance of existing theoretical perspectives but also provide empirical evidence supporting the integration of digital transformation, energy management, and green growth strategies. These insights contribute to the growing body of literature on sustainable business development and provide a foundation for future policy initiatives aimed at accelerating Vietnam's transition toward a digital and green economy.

CONCLUSIONS AND RECOMMENDATIONS

This study examined the relationship between digital transformation and energy efficiency among Vietnamese enterprises and explored its implications for sustainable development and green growth. The findings indicate that digital transformation has become an increasingly important driver of enterprise modernization in Vietnam, supported by the growing adoption of technologies such as artificial intelligence, big data analytics, the Internet of Things, cloud computing, and smart manufacturing systems. Despite significant progress in digital adoption, many enterprises continue to face challenges related to high energy consumption, technological limitations, and inefficient resource utilization. The results demonstrate that digital transformation contributes substantially to improved energy efficiency through multiple mechanisms, including smart energy management, process automation, predictive maintenance, and data-driven decision-making. These technologies enable enterprises to optimize production processes, reduce energy waste, enhance resource productivity, and improve overall operational performance. Furthermore, increased energy efficiency contributes to broader objectives associated with green growth and sustainable development by reducing carbon emissions, strengthening competitiveness, and supporting environmentally responsible business practices.

From a theoretical perspective, this study contributes to the existing literature by integrating digital transformation, energy efficiency, green growth, and sustainable development within a unified analytical framework. The findings provide empirical support for the Resource-Based View, Technology Acceptance Theory, and Green Growth Theory, highlighting the strategic role of digital technologies in promoting sustainable business development. From a practical perspective, the study offers valuable implications for policymakers and business leaders. The findings suggest that accelerating digital transformation can serve as an effective strategy for improving energy efficiency and supporting Vietnam's commitment to achieving net-zero greenhouse gas emissions by 2050. Investments in digital infrastructure, technological innovation, human capital development, and energy-efficient technologies are therefore essential for achieving long-term sustainability objectives. Although the study provides important insights, its findings should be interpreted in light of certain limitations. The analysis relies primarily on secondary data and focuses on broad enterprise-level trends rather than firm-specific evidence. These limitations may affect the ability to capture industry-specific dynamics and causal relationships in greater detail.

FUTURE STUDY

Future research should expand the analysis by utilizing primary survey data and firm-level datasets to provide more comprehensive evidence regarding the relationship between digital transformation and energy efficiency. The use of primary data would allow researchers to examine how specific digital technologies influence energy performance across different organizational contexts and enterprise sizes. In addition, future studies may employ advanced

econometric techniques, such as panel data analysis, structural equation modeling, or causal inference methods, to investigate the direct and indirect effects of digital transformation on energy efficiency and sustainability outcomes. Such approaches would contribute to a deeper understanding of the mechanisms through which digital technologies create economic and environmental value. Further research could also explore sector-specific differences among manufacturing, logistics, services, and high-technology industries. Comparative studies across industries would help identify best practices and determine which digital solutions generate the greatest improvements in energy efficiency. Moreover, future investigations may evaluate the long-term impacts of emerging technologies, including artificial intelligence, digital twins, and smart industrial systems, on green growth and sustainable development in developing economies.

Finally, cross-country comparative studies involving Vietnam and other ASEAN countries would provide valuable insights into the role of institutional environments, technological readiness, and policy frameworks in shaping the effectiveness of digital transformation strategies. Such research would contribute to the development of more effective policies aimed at promoting sustainable and energy-efficient economic growth.

REFERENCES

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99–120.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. MIS Quarterly, 37(2), 471–482.

Brundtland Commission. (1987). Our common future. Oxford University Press.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–340.

European Commission. (2019). The European Green Deal. European Commission.

General Statistics Office of Vietnam. (2024). Statistical yearbook of Vietnam 2024. Statistical Publishing House.

GeSI. (2015). #SMARTer2030: ICT solutions for 21st century challenges. Global e-Sustainability Initiative.

International Energy Agency. (2023). Energy efficiency 2023. IEA.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current

trends and future perspectives. Process Safety and Environmental Protection, 117, 408–425.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & Information Systems Engineering, 6(4), 239–242.

Ministry of Industry and Trade of Vietnam. (2024). Vietnam energy outlook report 2024. MOIT.

Ministry of Information and Communications of Vietnam. (2024). Vietnam digital transformation report 2024. MIC.

Organisation for Economic Co-operation and Development. (2023). OECD digital economy outlook 2023. OECD Publishing.

Organisation for Economic Co-operation and Development. (2024). Green growth indicators 2024. OECD Publishing.

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. Harvard Business Review, 92(11), 64–88.

Schwab, K. (2016). The fourth industrial revolution. World Economic Forum.

Stock, T., & Seliger, G. (2016). Opportunities of sustainable manufacturing in Industry 4.0. Procedia CIRP, 40, 536–541.

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. United Nations.

United Nations Development Programme. (2024). Human development report 2024. UNDP.

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. The Journal of Strategic Information Systems, 28(2), 118–144.

World Bank. (2021). Vietnam country climate and development report. World Bank.

World Bank. (2024). World development indicators 2024. World Bank.

World Economic Forum. (2023). The future of jobs report 2023. World Economic Forum.

Zhou, K., Liu, T., & Zhou, L. (2016). Industry 4.0: Towards future industrial opportunities and challenges. In Proceedings of the 12th International

Conference on Fuzzy Systems and Knowledge Discovery (pp. 2147–2152).

Zhou, P., Ang, B. W., & Zhou, D. Q. (2012). Measuring economy-wide energy efficiency performance: A parametric frontier approach. Applied Energy, 90(1), 196–200.