

**ON THE ISSUE OF DIGITAL TRANSFORMATION IN THE ENERGY SECTOR
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Abstract: This study focuses on the digital transformation of the energy sector of the Islamic Republic of Iran. In particular, key aspects of the implementation of digital technologies in the energy sector are examined, including their impact on production efficiency, cost reduction, and sustainable development. Challenges associated with the integration of digital solutions include big data management, cybersecurity, and infrastructure modernization. Special attention is paid to the role of digital technologies in improving energy efficiency and achieving climate goals. The study concludes that a strategic approach to the digitalization of the energy sector is essential.

Keywords: digital transformation, energy sector, energy efficiency, digital technologies, big data management, sustainable development.

Introduction. Energy is a fundamental factor in national development and security and a driving force necessary for the sustainable functioning of national economic systems [1]. Improving energy efficiency is a crucial step toward achieving the goal of affordable and clean energy. Since the Industrial Revolution and the widespread use of fossil fuels, global environmental and climate-related problems—such as the greenhouse effect, air pollution, and acid rain—have emerged and intensified. These problems negatively affect economic behavior and cause environmental damage during economic development. Rapid economic expansion and accelerated industrialization have led to a sharp increase in energy consumption. This extensive development model, combined with low energy efficiency, has become a major obstacle to economic transformation and modernization [2]. Continuous growth in energy consumption has resulted in increasing environmental pollution and ecological challenges, such as resource constraints limiting sustainable economic development. Energy efficiency is now widely recognized as a key factor in resource conservation, environmental protection, and sustainable development. An economic model based on large-scale growth with high energy consumption and pollution poses unprecedented challenges to environmental protection. At the same time, urban development can no longer ignore growing energy consumption and its environmental consequences [3]. Moreover, industrialization and urbanization processes are still ongoing, and energy consumption will continue to rise. The traditional fossil-fuel-based energy mix, such as coal, cannot be completely replaced in the short term. Under increasing climate and environmental pressure, energy conservation and greenhouse gas emission reduction have

become urgent priorities for governments worldwide. The energy sector, as the main source of carbon emissions, is under significant pressure to achieve deep decarbonization. Substantial progress in energy efficiency can contribute to a “green” technological revolution and is considered one of the most important policy tools for emission reduction [4].

Entering the 21st century, humanity has witnessed advances in life sciences, information technologies, quantum science, nanotechnology, energy technologies, and artificial intelligence. The development of new sciences and industries, business forms, and management models is reshaping modern industrial systems and transforming social production. The integration of advanced information technologies with energy infrastructure to promote the digital transformation of the energy sector is an important measure to enhance total factor productivity [5]. The International Energy Agency (IEA) believes that digital transformation is fundamentally reshaping the global energy system and creating unique opportunities for sustainable energy development. By optimizing the allocation of production factors, digital technologies can improve energy savings, cost optimization, forecasting, and risk management in traditional industries. They also significantly enhance energy efficiency in energy-intensive sectors such as transport, construction, and manufacturing. According to Bloomberg New Energy Finance (BNEF), achieving the 2°C global warming limit under the Paris Climate Agreement would require global investments of USD 15.1 trillion in solar and wind energy, batteries, and grid electricity by 2050 [6]. However, these investments alone are insufficient. Additional substantial investments in the digital transformation of energy systems are required. Total investment in energy infrastructure must increase by USD 92 trillion, reaching USD 173 trillion by 2050 to achieve net-zero emissions [7]. Governments worldwide are actively implementing digital technologies and promoting digital transformation across economic sectors [8]. The IEA report on digitalization of energy emphasizes that digital technologies offer new solutions to critical challenges in the energy industry by making production and operational models more efficient. Digital transformation enables energy systems to become more integrated, intelligent, efficient, reliable, and sustainable, fostering new business models and modernizing traditional energy strategies.

Digital technologies have a dual impact: they may increase energy consumption while simultaneously improving energy efficiency [9]. Although increased energy demand from digital devices must be carefully considered, digital development helps reduce losses in production processes, optimize operational and information flows, and improve energy management efficiency. Digital technologies can also enhance interdependence between energy producers and consumers, creating an “energy feedback” effect. Therefore, it is important to objectively assess the impact of digital technologies on energy efficiency and identify mechanisms through which digital transformation contributes to energy efficiency at economic and social levels [10].

The aim of this study is to develop innovative approaches to analyzing the role of new information technologies in energy transformation and energy efficiency improvement within Iran’s digital economy. The results will help companies and government institutions take timely measures to promote digital transformation of energy systems.

Analysis of Previous Studies. Despite the development of renewable energy and limited use of nuclear power, oil and natural gas are expected to remain the main sources of global energy consumption until 2040 [11]. Iran currently enjoys a significant competitive advantage in oil extraction costs due to a high share of onshore resources. However, depletion of onshore fields and a shift toward offshore investments make the development of offshore resources inevitable. While energy production processes are similar onshore and offshore, differences lie in equipment and operating costs, which significantly affect production costs. Offshore energy production is several times more expensive than onshore production. Digital technologies can optimize operating costs and improve safety and environmental protection in offshore operations (Figure 1).



Figure 1. Advantages of digital transformation in the energy sector

Reviewing the “Regulation on Production, Knowledge-Based, and Job-Creating Innovations in the Oil Industry,” approved by the Cabinet of Ministers in 2022, and analyzing its individual provisions, it can be concluded that it indirectly emphasizes the need to promote the use of digital technologies and foster digital transformation in energy-related industries. This, in turn, implies the development of networking to create an innovative ecosystem based on digital technologies. Given that Iran's oil industry is one of the most significant and profitable sectors in the country, increasing its efficiency and productivity through the use of digital technologies can significantly improve performance and profitability, ensure the required flow of information, enhance monitoring accuracy, and minimize risks. Furthermore, aspects such as intelligent maintenance, optimal labor allocation, rationalized water consumption, and simplified process design are becoming achievable through digital transformation. Digital transformation facilitates more efficient asset lifecycle management and operational efficiency, which improves strategic decision-making capabilities. Iran's total oil production costs are at the lower end of cost indicators, demonstrating the high competitiveness of companies based on the current costs of Iranian oil production. These costs are determined by the average level of onshore and offshore oil production, with offshore production being significantly more expensive (approximately \$3 per barrel). From a management perspective, Iran's competitive advantage in energy production costs is quite sustainable. Part of this advantage is due to the adoption of modern technologies, including digital technologies, in the energy sector. However, there is currently a lack of research on the use of digital data and its impact on energy production, particularly in Iran's offshore oil and gas industry. The main reason for this is the predominant dependence of Iran's oil production competitiveness on onshore resources. With onshore oil fields depleting and investment in offshore production increasing, it is essential to focus on the development and implementation of systems based on big data analysis in this area.

Research Results. Key aspects of digital transformation in Iran's energy production include:

- Data-driven decision-making using digital technologies;
- Reduced physical presence in hazardous environments through automation and remote control;

- Enhanced transparency and stakeholder trust;
- Strengthened governance in the energy sector;
- Integrated decision-making processes;
- Improved efficiency and productivity of equipment and personnel.

These findings are largely consistent with the results of a study [12], which identified aspects of digital transformation in organizations, although their study did not focus on any specific industry. The urgency of implementing digital transformation is emphasized by the following factors:

- the development of a variety of innovative digital solutions in the energy sector;
- pressure from stakeholders in the energy sector;
- requirements of international and national energy production regulations;
- the need to achieve higher cost-effectiveness and profitability in energy production;
- expanding employee capabilities in mastering and applying digital technologies;
- the need to optimize operational efficiency across various energy sectors;
- the need for optimal management of physical assets on offshore platforms;
- the need to maintain production and increase resource recovery.

In addition to the factors noted, there are a number of external conditions influencing the digital transformation of the energy sector. Among them are:

- infrastructure limitations in the communication networks of offshore platforms;
- data exchange security in the energy sector;
- the extent to which management uses data in decision-making;
- national norms and standards in the fields of safety, ecology, and data use;
- development of interactions between industrial enterprises, research centers, and start-ups related to digital transformation.

Other factors influencing the digitalization of energy production in Iran include management's decision-making authority and risk appetite; limitations in the organizational culture of industrial enterprises; employee awareness of digital transformation and its implementation; the extent to which data is used in management decisions; the lack of legal structures supporting digital transformation; technical barriers; and investment restrictions in digital technologies at the organizational level.

The study [13] identified three categories of factors facilitating digital transformation at the decision-making stage:

1. Organizational factors, including process improvement, improved working environment, vertical integration, management support, horizontal integration, and cost reduction.
2. External factors, including customer requirements, supply chains, innovation pressure, market factors, as well as regulatory and governance frameworks.
3. Individual factors, including employee support.

In Iran, thanks to its oil resources and as part of achieving the goals of economic and social development programs, many project-based organizations are currently implementing infrastructure projects in the country's oil and gas sector. For these organizations, due to the significant risks associated with the complexity of projects and the critical importance of preemptively accessing oil and gas resources before competitors, improving methods and utilizing modern project management structures is an urgent need.

According to the digital transformation model of project-based organizations in the Iranian oil and gas industry, digital transformation is a multi-level systemic process aimed at fundamental changes in various aspects of the organization. This includes modernizing operational processes, improving project services and products, enhancing stakeholder engagement, optimizing organizational relationships, managing project data and knowledge, and managing resources and physical assets. Based on this model, the drivers of digital transformation in these organizations are classified into three levels: internal, external, industry-specific, and managerial. These factors act as organizational drivers, providing the strategic prerequisites for digital transformation.

Digital transformation in these organizations is implemented within the framework of strategic requirements through the innovative application of digital technologies and the implementation of structural and behavioral changes, leading to both positive and negative consequences for the organization, related industries, and society as a whole.

During digital transformation, certain internal and external factors emerge as intervening elements, and overcoming them is critical to achieving the expected results. During the digital transformation process, strategic requirements must be regularly reviewed, based on monitoring its impact. Pressure from project stakeholders, the organization's operational needs, and industry factors are identified as driving forces, while collaboration within the industry is one of the strategic requirements of digital transformation. Key areas of focus include optimizing operational processes, improving project services and products, enhancing stakeholder engagement with the organization and projects, developing organizational relationships, managing project data and knowledge, and managing physical resources and assets.

The expected positive outcomes of digital transformation include increased operational efficiency, improved project production and management performance, strengthened communication within project teams, increased reliability and trust, customer satisfaction, improved workplace safety, and enhanced environmental protection. Furthermore, barriers associated with the project-oriented nature of activities are recognized as a distinguishing factor in this transformation.

Discussion. Digital transformation in project-oriented oil and gas organizations in Iran is a multi-level systemic process involving operational modernization, service improvement, stakeholder experience enhancement, data and knowledge management, and asset management. Expected benefits include improved operational efficiency, stronger communication, higher safety and environmental protection, increased customer satisfaction, and enhanced competitiveness. However, challenges such as information overload, cybersecurity risks, and data privacy concerns require careful management.

Leaders of project-oriented organizations in the Iranian oil and gas sector can anticipate the relevant activities, outcomes, and expected impacts of digital transformation before implementation begins. By considering the influencing factors, they can gain the necessary knowledge to ensure the continuity of the digital transformation process within the organization. Based on the conducted analysis, the following key aspects can be proposed for implementing the digital transformation model in project-oriented organizations in the country's energy sector:

- the need to focus on the drivers of digital transformation;
- strategic requirements for digital transformation;
- innovative application of digital technologies;
- the need for structural and behavioral changes within the organization.

Areas of improvement in the energy sector.

Innovative application of digital technologies facilitates fundamental changes at key points in operational processes, project services and products, stakeholder experience, organizational relationships, data and knowledge management, and resource and asset management. Examples of digital transformation include:

- changes in the volume and type of digital data;
- digitalization and multidimensional modeling of project operations;
- Ensuring fast, convenient, and unlimited employee access to project data and information;
- Accelerated data processing and decision-making;
- Improved knowledge management processes;
- Digital collaboration through the creation of virtual teams and continuous online communication between project teams;
- Improved resource assessment, allocation, and monitoring;
- Increased flexibility and responsiveness of project management;

- Changes in interactions with project clients;
- Phased delivery of project products;
- Intelligent asset management and the formation of ecosystems.

The exchange of digital information instead of paper documents, simultaneous 3D design and printing instead of 2D design, digital construction instead of physical construction, the use of automated payment systems, internal communications instead of interdepartmental dependencies, integrated processes instead of traditional work methods—all these are examples of digital transformation in the energy industry. In today's business world, no organization can independently implement innovations based on new technologies; cooperation with other organizations is necessary to create value-added products and continuously create value for stakeholders. Through strong partnerships, each organization can acquire the necessary competencies to develop innovative products and services, create digital platforms, and build an innovation ecosystem. Bringing together all stakeholders in a digital ecosystem facilitates the coordination of individual skills, tacit knowledge, and technological assets to achieve shared advantages in bringing innovative products to market [14].

Conclusion. Factors influencing the digital transformation process include technical, environmental, cultural, and structural factors, as well as human resource skills and knowledge. Identifying these factors and their associated risks plays a crucial role in developing a successful digital transformation strategy. Given limited organizational resources, it is not always possible to control all the diverse influencing factors. Therefore, it is recommended to allocate resources according to their impact on the success or implementation of digital transformation.

Digital transformation creates value for project-oriented organizations in the Iranian oil and gas industry. Its positive outcomes include increased operational efficiency, improved project and organizational performance, optimized project team communication, strategic differentiation, increased competitiveness, reliability, trust, customer satisfaction, and enhanced safety and environmental protection. However, digital transformation can also lead to negative consequences, such as information overload, increased cyber threats, and data breaches, requiring special attention from senior management.

List of sources used

1. J. Liu, Y. Xue, Z. Mao, M. Irfan, and H. Wu. "How to improve total factor energy efficiency under climate change: does export sophistication matter?" *Environ. Sci. Pollut. Res.* 2023. doi: 10.1007/s11356-022-24175-2.
2. B. K. Edziah, H. Sun, P. K. Adom, F. Wang, and A. O. Agyemang. "The role of exogenous technological factors and renewable energy in carbon dioxide emission reduction in Sub-Saharan Africa." *Renew. Energy.* 2022. doi: 10.1016/j.renene.2022.06.130.
3. M. Lu, L. Daixu, W. Peng, and M. Ruiqi. "Heterogeneous environmental regulation tools and green economy development: evidence from China." *Environ. Res. Commun.* 2023. doi: 10.1088/2515-7620/acb1f9.
4. H. R. Peng, Y. J. Zhang, and J. Y. Liu. "The energy rebound effect of digital development: Evidence from 285 cities in China." *Energy*, 2023. doi: 10.1016/j.energy.2023.126837.
5. Z. Cheng, X. Yu, and Y. Zhang. "Is the construction of new energy demonstration cities conducive to improvements in energy efficiency?" *Energy*, 2023. doi: 10.1016/j.energy.2022.125517.
6. D. Benatia, N. Johnstone, and I. Haščič. "Effectiveness of Policies and Strategies to Increase the Capacity Utilization of Intermittent Renewable Power Plants." *OECD Environ. Work. Pap. OECD Publ.* 2013.
7. S. Kim et al. "Perspectives of oxy-coal power plants equipped with CO₂ capture, utilization, and storage in terms of energy, economic, and environmental impacts." *Energy Convers. Manag.* 2022. doi: 10.1016/j.enconman.2022.116361.

8. Y. Shen and X. Zhang. "Intelligent manufacturing, green innovation technology and environmental pollution." *J. Innov. Knowl.* 2023. doi: 10.1016/j.jik.2023.100384.
9. K. Goldbach, A. M. Rotaru, S. Reichert, G. Stiff, and S. Gözl. "Which digital energy services improve energy efficiency? A multi-criteria investigation with European experts." *Energy Policy*. 2018. doi: 10.1016/j.enpol.2017.12.036.
10. H. Wu, M. Han, and Y. Shen. "Technology-driven energy revolution: the impact of digital technology on energy efficiency and its mechanism." *Front. Energy Res.* 2023. doi: 10.3389/fenrg.2023.1242580.
11. H. Heidari, M. Akbari, A. Souhankar, and R. Hafezi. "Review of global energy trends towards 2040 and recommendations for Iran oil and gas sector." *Int. J. Environ. Sci. Technol.* 2022. doi: 10.1007/s13762-022-03963-w.
12. P. C. Verhoef et al. "Digital transformation: A multidisciplinary reflection and research agenda". *J. Bus. Res.* 2021. doi: 10.1016/j.jbusres.2019.09.022.
13. K. Liere-Netheler, S. Packmohr, and K. Vogelsang. "Drivers of digital transformation in manufacturing". *Proceedings of the Annual Hawaii International Conference on System Sciences*. 2018. doi: 10.24251/hicss.2018.493.
14. Z. S. Kariani, R. V. Okorokov. Features of the implementation of ESG strategies for sustainable development in the activities of Iranian industrial companies // *Bulletin of the Academy of Knowledge*. 2024. No. 5(64). P. 664-669.