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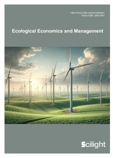

Article

Digitalization, Energy Systems, and Sustainable Development Goals: An Ecological Economic Analysis of EU Member States

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Abstract: Addressing climate issues has become an increasingly important global priority, particularly in the context of the digital and energy transition. Within the European Union (EU), the digital transition represents an essential pillar and crucial concern for all member states. Climate-related issues, energy sustainability, and digital and social transitions are the focus of the 2030 Agenda adopted by both the EU and the United Nations. The 17 Sustainable Development Goals target essential aspects of everyday life, revealing an interdependence between climate change and the digital, social, and energy transition. They underscore that we must protect the resources that humanity needs. In this paper, we contribute to the empirical deciphering of this inter-conditioning on two levels of research. First, we investigate how EU member states have evolved in the field of digital transition, with a particular focus on Romania. Second, we analyze the broader implications of the digital transition at the EU level and the impact of the adaptation of new technologies. The findings suggest that there needs to be a deeper, more nuanced understanding of the importance of the digital transition. Based on these findings, we propose several potential avenues for future research, including a detailed analysis of the subdimensions related to digital, social, and energy transitions.

Keywords: energy transition; digital transition; social transition; EU; artificial intelligence

1. Introduction

By many measurable standards, humanity is doing better than ever before. However, our ideas about the future are often characterized by worrying scenarios, particularly climate-related issues. Therefore, it is all the more important to develop a clear vision of what we want the future to look like.

The COVID-19 pandemic and repeated lockdown measures severely disrupted the global economy, although job losses were partially mitigated through extensive government support. While a temporary recovery began in the second half of 2020, a resurgence in infections during the autumn led to renewed restrictions from November 2020 onward, resulting in a significant decline in economic activity across nearly all sectors both during and after the pandemic [1]. This period highlighted the need to recognize the digital economy as a strategic priority supported by a clear vision, coherent policies, and robust investments in order to accelerate digital transformation and keep the European Union (EU) on track toward achieving the objectives of the Digital Decade [2–5].

One of the slogans for the United Nations' Sustainable Development Goals (SDGs) is "The World We Want". These goals were adopted in 2016 with a 15-year term (until 2030) and serve as a guiding framework for all countries. While SDG 13 focuses on climate action, some of the other goals compete with each other. For this reason, the conclusion of the UNE report is particularly important: In the context of climate change, both the modern economy and society are focusing on energy as a central pillar of development. The complexity of the energy transition is closely linked to the growing need for flexibility in industrial energy demand, making it essential to integrate technical, economic, and social dimensions. Existing energy networks represent the outcome of long-term investments in scientific research, technological innovation, human capital, infrastructure, and national as well as international energy policies. Moreover, per capita energy consumption serves as a strong indicator of a country's economic growth [6] and a key determinant of the quality of life experienced by its population [7,8].

The fundamental digital transformations taking place globally have had a major influence on the global energy system. During its ongoing transformation, the global energy system has been significantly impacted by various factors, such as technological innovation and political and geopolitical developments. Consequently, due to the high requirements of data security, the digitalization of the energy transition plays an essential role in the exchange and collection of large amounts of data. With the help of smart metering systems, such as the smart meter, real-time data on electricity production and consumption can be centralized and accessed [9]. Moreover, IT plays a key role in connecting manufacturing and production infrastructure with the electricity market and system. This is due to the need to define and configure information flows across company boundaries, that is, to expand the classic automation pyramid [10] to coordinate the interaction of various optimization services [11] and build on this to automate and standardize the entire energy flexibility marketing process [12].

This study aims to examine the interrelationships between digitalization, the energy transition, and sustainable development within the EU, with a particular focus on Romania. Specifically, the research seeks to assess the current level of digital and energy transition performance using relevant international indicators, to identify existing gaps and structural challenges, and to analyze the role of emerging digital technologies in supporting a more efficient and sustainable energy system. By providing both a comparative EU perspective and a national-level analysis, the study intends to contribute to a better understanding of transition readiness and to support the development of evidence-based policies aligned with the objectives of the European Green Deal, the Digital Decade, and the SDGs.

We first discuss concerns at the level of the European Commission regarding the digital and energy transition, followed by a review of the implications of the sustainable development objectives for the digital, ecological, and energy transitions. Next, we present the findings of a study based on energy and digitalization indices for EU member states, with Romania as an example. Finally, we briefly discuss our conclusions.

2. Research Methodology

Research is generally grounded in a systematic process that involves the collection and analysis of data to enhance understanding of specific concepts and phenomena. In this study, such an approach is applied to examine the digital, social, and energy transition at the EU level, complemented by illustrative national-level examples. This multidimensional transition has become a critical issue at both global and national scales and represents a key strategic objective for the EU.

Given the overarching aim of the study, the research can be characterized as exploratory in nature, employing a predominantly qualitative approach. The primary objective is to investigate the interrelationships between technological development, social dynamics, and energy transformation within the EU. To this end, the study first examines the main implications of the SDGs within the framework of European Commission policies. Subsequently, a comparative quantitative analysis is conducted across the 27 EU member states, based on relevant energy and digitalization indices, with a detailed focus on national-level conditions. The results of this analysis are presented in the subsequent section.

2.1. The Role of Artificial Intelligence in the Energy Transition

Statistical data analysis, together with the Internet of Things (IoT), is increasingly shaping everyday life, sometimes in ways we consciously recognize, but often in ways that go unnoticed. These technologies have rapidly penetrated numerous domains, and their vast potential is far from fully exploited. In particular, system manufacturers, enterprises, and the energy sector should actively engage with this digitalization instrument, which embodies significant economic power [2].

The IoT bridges the physical and digital worlds by enabling the collection and transformation of large volumes of data. Interconnected devices operate autonomously, adapt to changing conditions, and respond to predefined scenarios without requiring user intervention [13]. The resulting measurable values create substantial opportunities for efficiency gains, especially for system manufacturers, operators, and energy companies, provided that the collected raw data are accurately evaluated, analyzed, and effectively implemented.

The energy sector is undergoing a profound transformation driven by digitalization and the energy transition. The decentralization of energy systems, the integration of new electrical consumers, and the increasing share of fluctuating renewable energy sources have significantly raised system complexity. Managing this complexity represents one of the central challenges of the energy transition. Artificial intelligence (AI) methods offer powerful tools to exploit digital data streams optimally and to cope with the growing complexity of modern energy systems [14–16]. For the energy sector to fully benefit from AI technologies and assume a global leadership role in the digitalization of the energy transition, a sector-specific perspective is essential. The industry is evolving rapidly, driven not only by the energy transition but also by technological advancements and rising environmental awareness. To address the challenges posed by renewable energy integration and distribution, the energy sector increasingly relies on AI.

AI has gained widespread relevance across nearly all economic sectors. In particular, the implementation of an integrated energy transition and the intelligent interconnection of an expanding number of decentralized producers and consumers across sectoral boundaries highlight the significant potential of AI technologies and the high expectations associated with them [17]. The importance of AI in enabling the energy transition and establishing an efficient, climate-neutral energy supply continues to grow. As future energy systems become more diverse, advanced intelligent control systems are required. These systems are responsible for integrating various renewable electricity sources, such as wind, photovoltaic, hydropower, and fuel cell–based combined heat and power, with multiple consumption sectors, including electricity, buildings, industrial processes, and electromobility. This integration also encompasses the production of green hydrogen through electrolysis [18,19].

In energy systems characterized by fluctuating renewable generation, accurate forecasting of electricity production and consumption is increasingly crucial to maintaining system stability. In this context, innovative AI and machine learning methods have been developed over many years. These approaches are applied in collaboration with industrial partners or offered as services to support the energy transition.

AI also plays a key role in designing energy- and resource-efficient industrial manufacturing processes. It enables the modeling and optimization of production workflows, supports quality assurance, and contributes to the reduction of production waste. Today, AI is already deployed across various areas of the energy sector to ensure supply security. Since renewable sources such as wind and solar energy are not continuously available, energy surpluses and deficits must be balanced effectively. Intelligent algorithms determine optimal power distribution strategies, ensuring reliable energy supply. Surplus energy is redirected or stored, while shortages are compensated for through alternative energy sources. Owing to continuous learning mechanisms, these algorithms improve over time and operate with increasing efficiency [20].

To advance international cooperation and digitalization, digital and green dimensions should be systematically integrated into energy-related projects, partnerships, and cooperation agreements. EU member states should enhance financial support for such digital initiatives to mobilize additional resources for transformation. Furthermore, promoting the digitalization of the energy system should be explicitly included in the Horizon Europe work program.

2.2. The Impact of SDGs on the Digital Transition, Ecology, and Energy

Entrepreneurship in developing and emerging economies is shaped by a wide range of structural and institutional challenges. Entrepreneurs in these contexts frequently encounter barriers related to access to information, skills development, qualified labor, capital, support services, and robust social and business networks. In many cases, local education systems do not sufficiently foster entrepreneurial ambition, innovation, or risk-taking, and a culture that actively supports entrepreneurship is often underdeveloped. In addition, both financial and non-financial resources may be scarce or difficult to obtain. Despite these obstacles, entrepreneurial activity holds significant potential to stimulate economic growth, strengthen resilience, and promote social inclusion.

Energy plays a fundamental role in all aspects of economic and social activity. Modern, technology-driven societies depend heavily on reliable electricity supplies; however, nearly one billion people worldwide still lack access to electricity. This reality underscores the urgent need for a just and inclusive global energy transition that ensures universal access to energy while fully shifting toward renewable sources and improving energy efficiency.

Access to mains electricity cannot be taken for granted in many parts of the world. Modern energy systems are a cornerstone of national economic development and a prerequisite for poverty reduction. According to projections by the International Energy Agency (IEA) [21], global energy demand is expected to increase by approximately 40% by 2040, with the majority of this growth occurring in developing and emerging economies. Access to modern energy services significantly enhances quality of life and enables both small and large enterprises to achieve competitive production levels. Consequently, a reliable energy supply is a critical condition for investment, employment creation, and income generation.

At the same time, the challenges posed by climate change make it clear that current and future energy demand cannot be sustainably met through fossil fuel–based systems. In response to global sustainability challenges, all United Nations member states adopted the 2030 Agenda for Sustainable Development in 2015, establishing a comprehensive framework for global economic progress that balances social equity with ecological limits. Central to the agenda are the 17 SDGs, which guide international efforts toward sustainable development (Figure 1). Science and research play a critical role in supporting evidence-based decision-making and in developing solutions to major societal challenges. Within this framework, SDG 7 (affordable and clean energy) places particular emphasis on scientific advancement and technological innovation [22]. Achieving this goal requires reversing plans for expanding coal-fired power generation in certain countries through the accelerated deployment of renewable energy sources, enhanced energy efficiency, expanded electricity grids and storage infrastructure, and the future integration of "green" fuels. Countries with high and rapidly increasing energy demand, such as China and India, must be actively involved in this transformation. Beyond increasing renewable energy capacity, the effective integration of these resources into local and regional electricity markets is essential to the success of a global energy transition, necessitating substantial investment in modern energy systems, including grid expansion, cross-border electricity trade, energy storage technologies, and the digitalization of energy consumption and grid management. Development institutions, such as KfW, also support partner countries by helping adapt regulatory frameworks to enable the integration of new technologies into the energy sector.

Innovative technologies, particularly digital solutions, offer significant potential to accelerate the energy transition. Information and communication technologies (ICT) facilitate new business models and technical solutions for off-grid, mini-grid, and grid-connected energy systems. Technologies such as blockchain, virtual power plants, smart grids, electromobility, battery storage, Power-to-X applications, and innovative pricing mechanisms based on load or time-of-use must be actively promoted and scaled at the global level. At the same time, it is essential to recognize the strong interdependencies among the SDGs, as progress in one area often depends on advances in others. For instance, SDG 7 is closely linked to SDG 2 (zero hunger) and SDG 6 (clean water and sanitation), highlighting the importance of integrated, coordinated, and system-oriented approaches to sustainable development.

Figure 1. Sustainable development goals. Source: Own elaboration.

In recognizing the interdependencies among the SDGs, the European Semester framework has integrated their requirements since the 2020 cycle. This integration demonstrates a strong institutional commitment to incorporating sustainability into the coordination of EU economic and employment policies. Within this context, the Annual Sustainable Growth Strategy defines four principal dimensions that constitute a core pillar of the Recovery and Resilience Plan: the green transition, equal opportunities, digital transformation and productivity, and macroeconomic stability.

Notwithstanding these policy developments, progress in achieving environmental SDGs remains uneven. Consequently, the attainment of climate and environmental objectives will require additional, more targeted actions. Final energy consumption remains high and has decreased only gradually, while dependence on energy imports continues to be substantial. Although some progress has been made, the intensity of greenhouse gas emissions associated with energy use remains well above the EU-27 average. This underscores the significant potential for further advancement in relation to both SDG 7 and SDG 13. More broadly, SDG 13 and its associated targets remain relatively vague and lack binding or quantifiable commitments, such as explicit emission reduction goals. Furthermore, inconsistencies persist within the SDG framework. While climate mainstreaming is embedded in objectives related to agriculture and urban development, infrastructure investments with potentially adverse environmental and climate impacts are simultaneously promoted as key drivers of economic growth.

Nevertheless, the available evidence confirms that climate action constitutes a central pillar of the SDGs. Achieving the SDGs is not feasible without preventing severe climate change and systematically integrating climate risks across nearly all policy areas covered by the goals. Conversely, sustainable development progress is a prerequisite for achieving a largely emissions-free and climate-resilient economic transformation.

Significant advances have been made in several SDGs related to social inclusion and equal opportunities, particularly SDG 1 (no poverty), SDG 3 (good health and well-being), and SDG 8 (decent work and economic growth). However, achieving SDG 4 (quality education) remains challenging. Participation rates in post-secondary and adult education continue to lag behind the EU average, while school dropout rates have increased. In relation to SDG 10 (reduced inequalities), substantial disparities persist between EU and non-EU citizens. Progress in these areas is essential, as education is both a fundamental human right and a cornerstone of sustainable development. A well-educated population underpins poverty reduction, inequality mitigation, sustainable economic growth, and social cohesion. Education also contributes positively to health outcomes, women's empowerment, and broader social and economic participation. According to UNESCO, the global financing gap in the education sector is expected to widen by up to one-third as a consequence of the COVID-19 pandemic.

Romania has experienced notable growth in research and development (R&D) investment, supported by an expanding workforce in science, technology, and innovation, as well as an increasing number of patent applications. These developments contribute to relatively strong performance with respect to SDG 9 (industry, innovation, and infrastructure). Nevertheless, delays in investment remain evident. Accelerating investment in digital infrastructure would support economic recovery and help reduce the gap with other EU member states in the deployment of very high-capacity networks. While basic digital and software skills are relatively widespread, advanced and specialized digital competencies remain limited, leading to a significant shortage of ICT professionals.

Romania's status as a developing economy is also reflected in its progress toward SDG 8. At the same time, the country benefits from comparatively strong institutional frameworks, as indicated by its solid performance under SDG 16 (peace, justice, and strong institutions). However, persistent structural challenges continue to hinder overall progress. The achievement of SDG 17 (partnerships for the goals) is particularly critical, as progress across all other SDGs depends on access to financial resources, knowledge, and technology. Given the scale of these challenges, public funding alone is insufficient. Furthermore, governments worldwide have shown limited effectiveness in implementing SDG 17, a situation that has been further aggravated by the fiscal pressures resulting from the COVID-19 pandemic. This context underscores the urgent need for coordinated and collaborative action involving governments, the private sector, civil society, and international partners.

3. Results and Discussion

The World Economic Forum has developed the Energy Transition Index (ETI) as a tool to track energy transition progress at the national, regional, and global levels. The index is designed to reflect key objectives related to sustainability, energy security, and energy system performance. Given the diversity of global energy markets, policy frameworks, and interconnections, several indices have been developed worldwide to assess different aspects of the energy transition. While some studies continue to characterize the energy transition primarily as a shift in dominant fuels or technologies [23,24], there is increasing consensus that it also encompasses broader socioeconomic and political dimensions.

Currently, in addition to scientists studying the energy transition, several organizations are tracking this transition through different indicators. In the following list, we present the indices used by the most important organizations involved in the energy transition:

- World Bank [25–27]
- Energy Transition Index (ETI) of the World Economic Forum
- International Renewable Energy Agency (IRENA) [28]
- Energy Development Index (EDI) of the International Energy Agency (IEA) [21,29]
- International Atomic Energy Agency

- World Economic Forum Energy Architecture Performance Index (EAPI) from 2013 to 2017
- Global Energy Institute's Energy Security Index
- Multidimensional Energy Poverty Index (MEPI) of the World Bank
- Sustainable Energy Development Index (SEDI) of the World Bank
- The Energy Trilemma Index of the World Energy Council
- Climate Action Tracker [30]
- PBL Netherlands Environmental Agency Pledge [31]
- The Green, Digital, and Competitive SME Index

The ETI was calculated for 114 countries for the first time in 2018 by McKinsey in cooperation with the World Economic Forum. This index uses 40 indicators to measure the state of the energy transition ("system performance") and the initial political, economic, and social conditions required for successful implementation ("transition readiness"). Next, we present an extract from the analysis of the Global Economic Form for the year 2021 for EU member countries.

In the context of the energy transition, Romania does not excel compared to the rest of the EU countries. In the overall ETI ranking, Romania ranks 38 out of 115. However, in the European context, 19 countries do better than Romania. The index shows that Romania faces greater energy challenges than many other EU countries; this becomes particularly clear when looking at the Energy System Structure Indicator. In terms of system performance, which measures the progress of the energy transition in the dimensions of environmental and climate protection, economic efficiency, and security of supply, Romania is only 30th among 115 countries; among EU countries, it is 14th. The factors responsible for this are, among others, the high electricity prices for private households; Romanian private households currently pay 38.38 USDc/kWh compared to the overall average of 27.22 USDc/kWh. In the case of the transition readiness indicator, Romania ranks 42 out of 115 countries, with a rank of 21 at the EU level, which indicates that Romania is still at the beginning of the road in terms of the energy transition (Table 1).

Table 1. Synthesis of the Energy Transition Index.

	Population (Millions)	GDP (Current $, Billions)	GDP Per Capita (Current $)	Energy Transition Index	System Performance	Transition Readiness
AT	8.877	445	50,138	75.2	75.2	75.2
BE	11.48	533	46,421	67	67.8	66.3
BG	6.976	69	9828	58.6	60.5	56.7
CY	1.199	25	27,858	60.5	64.5	56.6
CZ	10.67	252	23,495	62.5	68.2	56.9
DE	83.13	3861	46,445	68.3	67.4	69.2
DK	5.819	350	60,170	76.5	74.8	78.2
EE	1.327	31	23,723	68.6	67.8	69.4
EL	10.72	210	19,583	60	66.7	53.2
ES	47.08	1393	29,600	68.3	69.7	66.9
FI	5.52	269	48,783	73.2	73.5	73
FR	67.06	2716	40,494	71	77.6	64.4
HR	4.068	61	14,936	66.6	71.8	61.4
HU	9.77	163	16,732	65.4	71	59.8
IE	4.941	389	78,661	68.8	70.2	67.5
IT	60.3	2004	33,228	66.1	71.2	61.1
LT	2.787	55	19,602	68.7	72.6	64.9
LU	0.6199	71	114,705	63.9	62.1	65.7
LV	1.913	34	17,829	70.7	73.1	68.4
MT	0.5027	15	29,821	63.8	68.4	59.3
NL	17.33	907	52,331	70.9	71.2	70.6
PL	37.97	596	15,693	57.7	63.7	51.8
PT	10.27	239	23,252	68.2	71.6	64.8
RO	19.36	250	12,920	64.3	70.3	58.4
SE	10.29	531	51,615	78.6	84.4	72.7
SI	2.088	54	25,946	65.6	70.8	60.4
SK	5.454	105	19,266	63.1	68.3	57.9
EU				67.11481	70.16296	64.1

Source: Own elaboration based on data from World Economic Forum.

The Green, Digital, and Competitive SME Index, developed by the Lisbon Council, is based on an innovative methodology structured around three core pillars: (i) Green**,** which assesses the extent to which small and medium-sized enterprises (SMEs) are reducing emissions and improving energy efficiency; (ii) Digital, which evaluates the pace at which SMEs adopt modern digital technologies across their operations; and (iii) Competitive**,** which measures business growth and performance in international markets. The index ranks Romania in 25th and 27th place for the green and digital pillars, respectively. According to the index results, emission reduction is the only dimension in which Romania's SMEs are classified within the green performance zone (Table 2).

Table 2. Index of SMEs.

	Digital Transition			Green Transition			SME Competitiveness		
	SME Digitalization	E-Commerce	Digital Skills	Natural Resource Conservation	Emission Reduction	Green Output	Exports	Productivity	Growth
AT	Green	Yellow	Yellow	Yellow	Yellow	Green	Green		Red
BE	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Red
BG	Red	Red	Red	Red	Green	Red	Green	Red	Yellow
CY	Yellow	Red	Green	Yellow	Red	Red	Yellow	Yellow	Red
CZ	Red	Green	Yellow	Yellow	Red	Red	Red	Yellow	Red
DE	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red
DK	Green	Green	Green	Red	Green	Green	Yellow	Green	Red
EE	Yellow	Yellow	Yellow	Red	Green	Yellow	Green	Yellow	Red
EL	Red	Yellow	Red	Yellow	Red	Yellow	Red	Red	Green
ES	Yellow	Yellow	Yellow	Green	Red	Yellow	Red	Yellow	Green
FI	Green	Green	Green	Yellow	Red	Green	Green	Green	Green
FR	Yellow	Yellow	Red	Red	Green	Green	Red	Yellow	Red
HR	Yellow	Green	Yellow	Red	Red	Red	Red	Red	Red
HU	Red	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Red	Yellow
IE	Green	Green	Green	Red	Green	Yellow	Red	Green	Green
IT	Yellow	Red	Red	Yellow	Red	Yellow	Red	Yellow	Red
LT	Yellow	Green	Red	Red	Yellow	Yellow	Green	Red	Red
LU	Green	Red	Yellow	Yellow	Red	Green	Yellow	Yellow	Red
LV	Red	Red	Red	Red	Red	Yellow	Green	Red	Red
MT	Green	Yellow	Green	Yellow	Green	Yellow	Red	Green	Green
NL	Green	Green	Green	Yellow	Red	Green	Green	Green	Green
PL	Red	Red	Yellow	Red	Green	Red	Yellow	Red	Yellow
PT	Yellow	Red	Yellow	Red	Red	Yellow	Yellow		Green
RO	Red	Red	Red	Yellow	Green	Red	Red	Red	Red
SE	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow
SI	Red	Yellow	Red	Red	Red	Green	Green	Yellow	Yellow
SK	Red	Red	Red	Green	Red	Green	Green	Red	Red

Green—progress stalled or reversed; yellow—progress too slow for goal achievement; red—progress on schedule for goal achievement. Source: Own elaboration based on data from Eurostat and https://gdc.lisboncouncil.net/en/ (accessed on 20 October 2025) [32].

To analyze the multiple dimensions of digitalization and their effects on digital ecology and the energy transition, this study relies on the Digital Economy and Society Index (DESI). The DESI offers a comprehensive assessment of Europe's digital performance and has been monitoring the digital development of EU member states since 2014. The index provides annual country profiles that assist member states in identifying priority areas for intervention, complemented by thematic chapters that deliver EU-wide analyses across key digital policy domains. The DESI consolidates indicators within four principal dimensions: (i) human capital, (ii) digital infrastructure, (iii) integration of digital technologies, and (iv) digital public services.

Through the increasing "algorithmization" of processes, digitalization reshapes power structures by enabling the control and coordination of technical systems, human behavior, and, by extension, social processes. This development underscores the necessity of ensuring transparency and accountability in algorithmic decision-making, coupled with robust data protection standards. In the energy sector, effective regulation of the volatility and flexibility of both energy generation and consumption is critical to achieving a successful energy transition. To this end, cellular and autonomous system structures, where autonomy refers to technical and social independence rather than complete self-sufficiency, should be promoted alongside regional supply security frameworks and mechanisms for democratic participation by civil society. Importantly, the energy savings achieved through digital solutions must clearly exceed the additional energy and resource consumption associated with digital technologies themselves.

The 2022 DESI report, based primarily on data from 2021, assesses the progress made by EU member states in advancing digitalization. In response to the COVID-19 pandemic, most countries intensified their digital transformation initiatives. However, significant challenges persist, including ongoing digital skills shortages, obstacles faced by small and medium-sized enterprises in adopting and integrating advanced digital technologies, and delays in the rollout of next-generation 5G networks.

Based on Figure 2, we observe mixed results for the basic dimensions of the DESI, particularly in the case of human capital, where Romania ranks last on this list. Its level of internet usage is the lowest in the EU, and in the case of advanced development skills, the country ranks 20th among 27 nations. Although Romania has high-performance networks, it does not necessarily have the requisite skills to use them. In terms of connectivity, the country performs quite well, occupying 15th place. More specifically, it obtains first place in the broadband price index, sixth place in fixed broadband coverage, and 13th place in fixed broadband take-up. However, it ranks 21st in mobile broadband because there is still a digital divide in the provision of this facility between cities and rural areas. Therefore, it is evident that there is still much to be done to achieve the goals of the digital decade, particularly full coverage of all Romanian households, by 2030. Thus, increasing the capacity of the civil engineering sector is crucial.

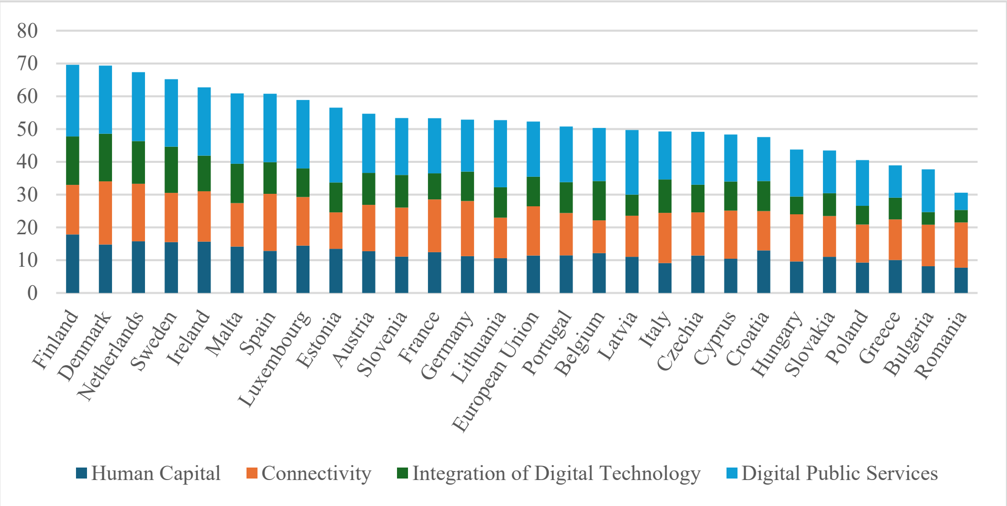

Figure 2. Digital Economy and Society Index by four main dimensions. Source: Own elaboration based on data from DESI https://digital-strategy.ec.europa.eu/en/policies/desi (accessed on 20 October 2025).

In the category of the integration of digital technology by companies and in public services, Romania ranks last among the 27 countries; this indicates that there is still a vast scope for improvement in these sectors to enhance the digitalization process so that the country can successfully position itself as the most highly ranked in terms of the DESI. At present, Romania is far from the corresponding goal of the digital decade, which is for at least over 90% of SMEs to reach basic digital intensity.

Romania ranks 27th in the EU for digital public services, indicating its poor performance in this field, despite several government initiatives to accelerate digitalization in the public sector. The country is also ranked 27th in the proportion of internet users using e-government, which is unsurprising in light of the previous discussion on the digital state. From a broader perspective, the majority of EU member states have made progress in terms of digital transformation, although the application of AI, cloud services, and big data is quite low.

In recent years, digital platforms have proliferated across numerous business sectors, serving as intermediaries that connect customers and suppliers while enabling the delivery of innovative services. Although the term “platform” is widely used in this context, its definition remains ambiguous and inconsistently applied in the literature [33]. In practice, IT platforms are extensively employed to support the digitalization and networking of production systems, while digital services such as predictive maintenance and the optimization of production process parameters are increasingly adopted [34].

The European Commission’s proposal for the “Path to the Digital Decade”, which has been endorsed by the European Parliament and EU member states, aims to strengthen cooperation between national governments and EU institutions across all dimensions assessed by the DESI. This initiative provides member states with a structured framework for joint commitments and the implementation of transnational projects designed to enhance collective competitiveness, resilience, and strategic autonomy in a global context.

Despite continued leadership in digital performance by countries such as Finland, Denmark, the Netherlands, and Sweden, even these frontrunners face persistent challenges in critical areas, including the diffusion of advanced digital technologies such as AI and big data analytics (Figure 3). A widespread shortage of relevant digital skills remains a major bottleneck, slowing overall progress and increasing the risk of digital exclusion across European societies (Figure 4).

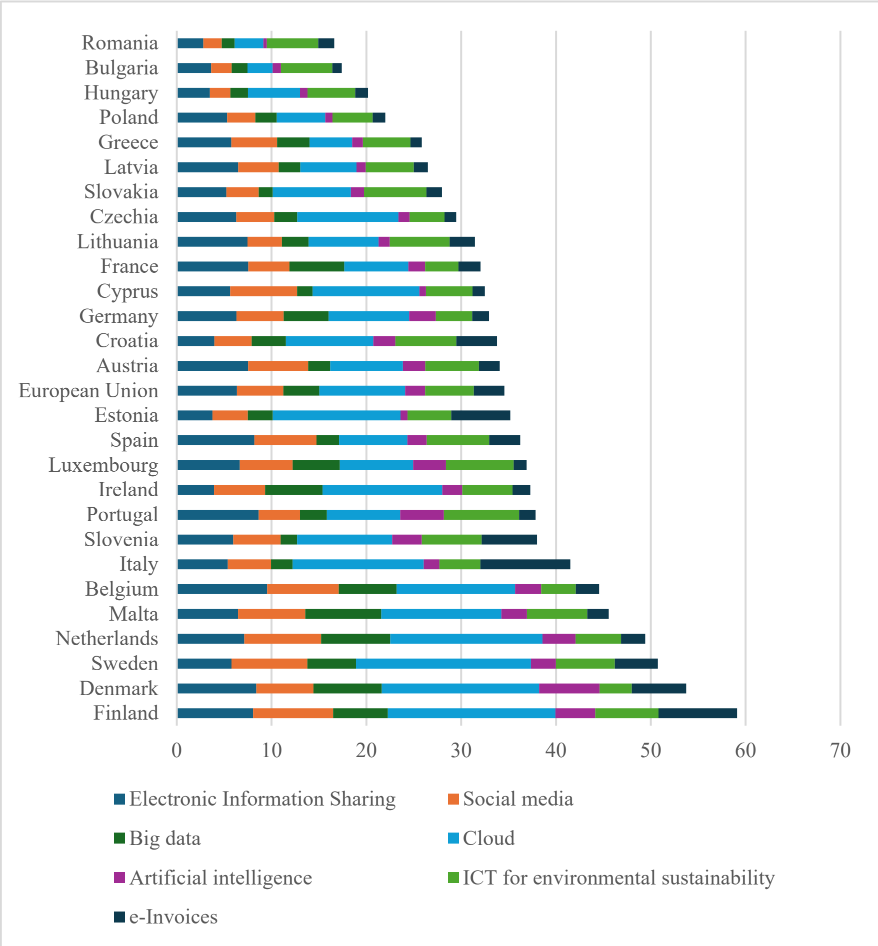

Figure 3. Digital technologies for businesses. Source: Own elaboration based on data from DESI https://digital-strategy.ec.europa.eu/en/policies/desi.

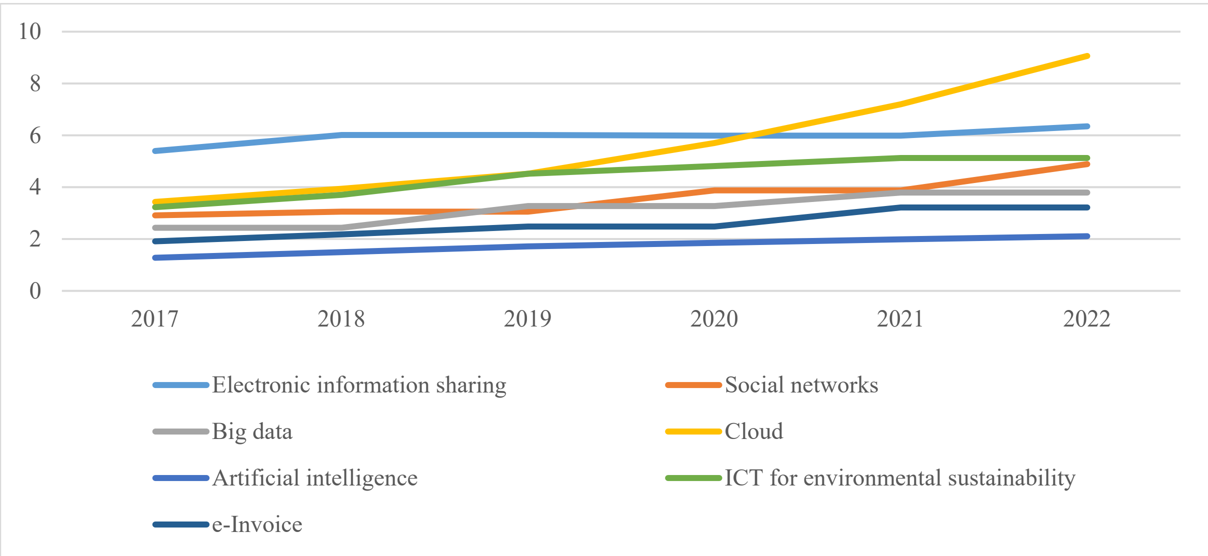

Figure 4. Evolution of digital technologies for business. Source: Own elaboration based on data from DESI https://digital-strategy.ec.europa.eu/en/policies/desi.

As noted in Table 3, there is a positive trend of convergence at the level of EU member states. Within the EU, this process of improving the level of digitalization continues; even the member states that started this process on the backfoot are trying to align with the member states that are already at a more advanced stage.

A blockchain is a chain of data that is stored on multiple computers. This could be, for example, data about the amount of electricity exchanged. The chain grows as new blocks are first verified and then chronologically attached to the end. The blockchain is not on a central server, but each user has their own complete copy. Each new block is linked to the previous block and verified by checksums. This makes blockchains unbreakable. All participants authenticate each other, and manipulation is excluded. Blockchain makes business models without intermediaries possible.

The transformation of the energy supply also has an impact on financial markets. The goal is explicitly stated in the climate change agreement: "Align finance flows with a path to low greenhouse gas emissions and climate-resilient development." An analysis of opportunities and risks shows that the financial sector would benefit from an orderly transition to a low-carbon economy.

Table 3. Digital technologies for EU business.

	Digital Technologies for Businesses						
	Electronic Information Sharing	**Social Media**	**Big Data**	**Cloud**	**Artificial Intelligence**	**ICT for Environmental Sustainability**	**E-Invoices**
Austria	7	8	18	18	11	11	14
Belgium	1	4	4	9	8	25	11
Bulgaria	25	26	24	27	22	12	27
Croatia	22	20	11	13	12	6	7
Cyprus	18	6	25	10	26	18	24
Czechia	14	19	16	11	18	24	25
Denmark	3	9	3	3	1	27	5
Estonia	24	21	15	6	25	20	3
Finland	5	1	7	2	3	3	2
France	6	17	6	21	15	26	12
Germany	13	13	10	14	7	23	16
Greece	17	14	12	25	20	16	26
Hungary	26	25	22	23	23	17	22
Ireland	23	11	5	8	13	14	15
Italy	19	15	19	5	16	21	1
Latvia	11	18	20	22	21	15	20
Lithuania	8	22	14	19	19	9	9
Luxembourg	10	10	9	16	5	2	21
Malta	12	5	1	7	9	7	13
Netherlands	9	2	2	4	4	19	10
Poland	20	24	21	24	24	22	23
Portugal	2	16	13	17	2	1	17
Romania	27	27	27	26	27	13	18
Slovakia	21	23	26	15	17	4	19
Slovenia	15	12	23	12	6	8	4
Spain	4	7	17	20	14	5	8
Sweden	16	3	8	1	10	10	6

Source: Own elaboration based on data from DESI https://digital-strategy.ec.europa.eu/en/policies/desi.

4. Conclusions

Anticipating future developments requires a thorough understanding of current trends and prevailing phenomena across multiple domains. Within this context, particular attention must be given to the energy transition. The ETI functions as a valuable analytical instrument for consolidating a wide range of energy-related variables and indicators derived from international datasets. These indicators reflect critical aspects of energy system performance and readiness for transition. Accordingly, a detailed examination of ETI data facilitates the identification of areas where targeted policy and investment interventions can be effectively implemented. Furthermore, the historical information embedded in the index supports the formulation of informed projections and scenario-based analyses.

Despite current efforts, Romania is still ranked last among the 27 EU states according to the DESI; it occupies 19th place in the ETI, 14th place in system performance, and 21st place in transition readiness. In light of the objectives set by the government, it is particularly important to move on to the implementation aspect, because if every household is to have a connection by 2030, the expansion of the network must be constantly accelerated and simplified. However, the expansion of digital infrastructure is a shared task and, therefore, is only possible together.

Furthermore, AI can and must be promoted in Romania in such a way that several objectives can be achieved at the same time: the faster elimination of coal-based energy production, sectoral integration based on renewable energies in the transport, heat, gas, and industry sectors, and net zero greenhouse gas emissions by the mid-century.

However, policies should avoid the use of AI for the energy transition in ways that ignore the risks instead of making them more manageable.

Greater energy flexibility from consumers, particularly through demand management, is an important element in achieving climate goals and overcoming the challenges of the energy trilemma. The energy industry offers great potential for this, which has not yet been sufficiently exploited. However, changes in the electricity market are making it necessary to position companies for the future.

The dynamic change in the energy industry in relation to the classic challenges of integrating new IT continues to provide significant scope for cooperation and interdisciplinary research. By means of digitalization, the energy system can be made more efficient, which must be seen as a necessity to ensure a successful energy transition. However, we must note that the energy system is still lagging behind other economic fields in terms of digitalization. The existing specialized literature indicates that certain concerns in this field need to be addressed and will likely go through a digital transition in the future. However, this discourse on the digital transition must account for a number of factors that may influence this process significantly, such as the decentralization of the energy system and increases in price that result in the generation of electricity by consumers. Therefore, in the future, many network clients may evolve from pure consumers to producers. From a long-term perspective, a series of changes in the structure of the energy system will certainly appear at the level of the ducks.

This study examined the relationship between digitalization, energy transition, and sustainable development in the EU, with a particular focus on Romania. The main findings can be summarized as follows:

- Romania ranks among the lowest-performing EU countries in overall digital development (DESI).
- Significant gaps persist in advanced digital skills and ICT human capital.
- Digital technology adoption by businesses and public administration remains limited.
- Romania shows moderate energy system performance but low transition readiness (ETI).
- The energy sector still lags behind in digitalization despite the strong potential of AI, smart systems, and data-driven solutions.
- Achieving the objectives of the Digital Decade and climate neutrality requires accelerated investment in infrastructure, skills, and institutional capacity.

These results highlight the need for stronger policy implementation, increased investment, and coordinated action among public authorities, businesses, and society to accelerate the digital and energy transition in Romania.

Future research should aim to develop more detailed and sector-specific analyses of the interactions between digitalization, energy transition, and sustainable development. Particular attention should be given to the impact of advanced technologies such as AI, big data, and smart energy systems on improving energy efficiency, system flexibility, and the large-scale integration of renewable energy sources. In addition, further studies should address the social and institutional dimensions of the transition, including the development of advanced digital skills, the reduction of regional and urban–rural disparities, and the capacity of public administration and small and medium-sized enterprises to adopt digital solutions. For Romania, future work should also evaluate the effectiveness of public policies and investment strategies aimed at accelerating digital infrastructure development and strengthening transition readiness. Such research would contribute to more effective policy design and support the achievement of the European Digital Decade objectives and the SDGs in a sustainable, inclusive, and resilient manner.

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Data Availability Statement

The data used in this study are publicly available from official sources, including the Digital Economy and Society Index (DESI), the Energy Transition Index (ETI), and other international databases referenced in the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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