

Navigating the Twin Transition: Digital and Ecological Transformations in the European Union*

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The European Union (EU) is currently navigating a complex but potentially transformative period characterized on one side by the need of ecological sustainability and, on the other side, by the digital revolution's deep impact on society and the economic system as a whole¹.

This period has been named with the term “twin transition”² so to emphasize the convergence of the two aforementioned transformations, which present both unprecedented opportunities and significant challenges for EU economic, social, and environmental future, the so called “trilemma”³. This paper provides an analysis of the interplay between digital and eco-

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¹ European Commission, *Towards a Green & Digital Future*, in publications.jrc.ec.europa.eu, 14 March 2025; European Commission, *Fair transition working papers, policy briefs and seminars*, in employment-social-affairs.ec.europa.eu, 14 March 2025; European Commission, *Fair green and digital transitions, research*, in employment-social-affairs.ec.europa.eu, 24 March 2025; EASSH, *Re&I for a Fair Digital Transition, 2024*, in op.europa.eu, 14 March 2025; EASSH, *Re&I for a Fair Green Transition, 2024*, in eassh.eu, 14 March 2024.

² B. Vermeulen - A. Pyka, *The Twin Digital and green Transition: Paradigm Shift or Tech Fix?*, in *Journal of Innovation Economics & Management*, 3, 2024, 1 ss.; Z. Kovacic - C. Garcia Casanas - H. March, *The twin green and digital transition: High-level policy or science fiction?*, in journals.sagepub.com, 14 March 2025; D. Diodato - E. Huergo - P. Monicada Paternò-Castello - F. Rentocchini - B. Timmermans, *Introduction to the special issue on “the twin (digital and green) transition: handling the economic and social challenges”*, in *Industry and Innovation*, 7, 2023, 755 ss.

³ M. Mandelli - S. Sabato - M. Jessuola, *EU Economic Governance and the Socio-Ecological Transition: Towards a More Sustainable European Semester?*, in *Politiche Sociali*, 3, 2021, 619 ss.; S. Sabato - M. Mandelli - M. Jessuola, *Towards an EU eco-social agenda? From Europe 2020 to the European Green Deal*, in M. Schoyen - B. Hvinden - M. D. Leiren (eds.), *Towards Sustainable Welfare States in Europe*, Cheltenham, 2022, 199 ss.

logical transitions within the EU context, exploring the theoretical framework of the two transitions and the role of digital technologies as enablers of ecological sustainability but at the same time as tools with a profound yet often overlooked environmental impact. The further analysis of the EU's policy framework will be crucial to show its implications for economic competitiveness, social equity, and the realization of a just transition.

1. Introduction

The need to address ecological challenges, most notably climate change, carbon dioxide emissions and fossil fuels, is crucial nowadays and felt as an imperative by many people⁴. This need coexists with the digital revolution's deep impact on everyday life, society and the economic system in every part of the world, taking the shapes of a real global shift⁵.

As regards the EU, these two transformative forces are increasingly recognized not as independent, but as deeply intertwined and mutually influential. This is why they are more and more frequently referred to as the "twin transition"⁶.

The EU is playing a crucial role in this transition, setting ambitious goals for both ecological sustainability and digital fairness. The main example of this is the European Green Deal (EGD), an initiative aimed at achieving zero net emissions of greenhouse gases by 2050⁷, but the Digital Decade is also important as it seeks to ensure EU digital leadership through citizens and businesses' empowerment⁸.

The basic assumption of these initiatives is that digital technologies can act as key enablers for achieving sustainability and reducing the environmental impact of numerous economic sectors, helping them to transition towards a circular economy⁹.

However, the synergy between digital and ecological transitions is not automatic since it can lead to trade-offs and negative externalities, as is the case with the environmental footprint of digital infrastructures, AI and data centres¹⁰.

From all these facts, it can be easily deduced that careful and future-proofed policy considerations are fundamental, and delving into the theoretical

⁴ S. Lange - L. Denick, *Digital Reset. Redirecting Technologies for the Deep Sustainability Transformation*, Berlin, 2022.

⁵ *Ibid.*

⁶ B. Vermeulen - A. Pyka, *The Twin Digital and green Transition*, cit., 1 ss.; Z. Kovacic - C. Garcia Casanas - H. March, *The twin green and digital transition*, cit.; D. Diodato - E. Huergo - P. Monicada Paternò-Castello - F. Rentocchini - B. Timmermans, *Introduction to the special issue on "the twin (digital and green) transition"*, cit., 755 ss.

⁷ European Commission, *The European Green Deal*, in commission.europa.eu, 24 March 2025.

⁸ European Commission, *Europe's Digital Decade*, in digital-strategy.ec.europa.eu, 24 March 2025.

⁹ M. Draghi, *The Future of European competitiveness. Part A*, in commission.europa.eu, 24 March 2025.

¹⁰ *Ibid.*

framework regarding the twin transition must be the starting point of this analysis.

2. A Theoretical Framework

Understanding the twin transition requires adopting various points of view. To this end, the so called “Multi-Level Perspective” (MLP) provides a valuable framework for analyzing how digital technologies can challenge and potentially transform the dominant fossil-based regime¹¹. MLP is able to highlight the interplay between technological progress, established socio-economic regimes, and external pressures in driving systemic change. In this context, the concept of digital sustainability has emerged to address the relationship between digital technologies and sustainability goals¹². More specifically, digital sustainability encompasses two dimensions: on one side, Green Information Systems (Green IS), that is the design and implementation of technologies that contribute to sustainable business processes; on the other side, Green Information Technologies (Green IT), mainly focused on energy and equipment utilization, including data centres’ energy consumption, electronic waste, and devices’ manufacturing carbon footprint¹³.

While some scholars have emphasized the potential for a mutually reinforcing process where digitalization and sustainability transformations accelerate each other¹⁴, other scholars have battled against the so called “digital solutionism”, regarded as an overly optimistic view of digital technologies as default solutions to sustainability challenges, calling for a critical assessment of their material impact and potential unintended consequences¹⁵.

In particular, Adi Kuntsman and Imogen Rattle, researchers respectively at the University of Manchester and at the University of Leeds, have proposed a «paradigmatic shift in sustainability studies» aimed at de-biasing current literature and embracing a more pragmatic and policy-oriented approach towards the twin transition¹⁶.

¹¹ K. Vestkioja - R-M. Soe - E. Kisel, *Implications of digitalization in facilitating socio-technical energy transitions in Europe*, in *Energy Research & Social Science*, 91, 2022, 2 ss.; D. Loorbach - N. Frantzeskaki - F. Avelino, *Sustainability Transitions Research: Transforming Science and Practice for Societal Change*, in *Annual Review of Environment and Resources*, 42, 2017, 599 ss.

¹² F. De Felice - A. Petrillo, *Green Transition: The Frontier of the Digicircular Economy Evidenced from a Systematic Literature Review*, in *mdpi.com*, 14 March 2025; A. Travassos Rosario - J. Carmo Dias, *Sustainability and the Digital Transition: A Literature Review*, in *mdpi.com*, 14 March 2025.

¹³ T. Lynn - P. Rosati - D. Kreps - K. Conboy, *Digital Sustainability: Key definitions and Concepts*, in T. Lynn - P. Rosati - D. Kreps - K. Conboy (eds.), *Digital Sustainability. Leveraging Digital technology to Combat climate Change*, London, 2024, 1 ss.

¹⁴ *Ibid.*

¹⁵ A. Kuntsman - I. Rattle, *Towards a Paradigmatic Shift in Sustainability Studies: A Systematic Review of Peer Reviewed Literature and Future Agenda Setting to Consider Environmental (Un)sustainability of Digital Communication*, in *Environmental Communication*, 5, 2019, 567 ss.

¹⁶ *Ibid.*

Other contributions have focused on applying the so called “Deep Transitions” (DT) framework, proposed by Johan Schot and Laur Kanger from the University of Sussex¹⁷, on twin transition’s studies, advocating for a radical and systemic turn embracing not just new technologies, but individuals, institutions and society as a whole.

These contributions have helped showing, through a historical point of view, that technological transitions tend to be faster than energy ones, implying a potential imbalance in the twin transition that necessitates proactive policy interventions to ensure that the decarbonization agenda, as set out by the EGD, keeps pace with the ever-changing digital sector¹⁸.

In this context, a fundamental role is played by Mario Draghi’s recent Report on European competitiveness, which lays out clear and multifaceted recommendations on how Europe should boost its economic growth through innovation, technology and AI¹⁹. The Report focuses on both technology as an enabler and as a barrier of the ecological transformation, and so does this paper in the following paragraphs.

3. Technology as an Enabler of the Ecological Transformation...

EU intervention on the twin transition crosses various sectors and policy domains. In general, digitalization is envisioned as a key enabler for enhancing resource efficiency and promoting economic circularity²⁰.

For instance, digital product passports are being explored as means to improve businesses’ transparency and accountability by providing consumers with accessible and comprehensive information about product lifecycles, material composition, and repair possibilities²¹.

In the energy sector, the application of smart technologies together with users’ nudge towards responsible energy consumption are central to the reduction of fossil fuels’ usage²². The digitalization of the Estonian electricity sector serves as a guiding example of this, highlighting the benefits for both businesses and consumers²³.

Undoubtedly, realizing interoperable, Europe-wide energy data access requires standardized data protection laws among Member States, robust

¹⁷ J. Schot - L. Kanger, *Deep Transitions: Emergence, Acceleration, Stabilization and Directionality*, in *papers.ssrn.com*, 14 March 2025.

¹⁸ R. Fouquet - R. Hippe, *Twin transitions of decarbonisation and digitalisation: A historical perspective on energy and information in European economies*, in *Energy Research & Social Science*, 91, 2022.

¹⁹ M. Draghi, *The Future of European competitiveness. Part A*, cit.

²⁰ *Ibid.*

²¹ European Data, *EU’s Digital Product Passport: Advancing transparency and sustainability*, in *data.europa.eu*, 14 March 2025.

²² K. Vestkioja - R-M. Soe - E. Kisel, *Implications of digitalization in facilitating socio-technical energy transitions in Europe*, cit., 8 ss.

²³ *Ibid.*

consent management, and adequate transparency²⁴. These are all essential elements to foster users' environmental awareness and to make green energy services' uptake scalable.

Artificial Intelligence (AI) and big data analytics, on their part, play a crucial role in the twin transition, since they can improve Environmental, Social, and Governance (ESG) reporting quality by streamlining businesses' data collection, enhancing in this way the collection of large volumes of data²⁵.

Starting from AI, it is identified as a General Purpose Technology (GPT) with a potentially systemic impact on firms' eco-innovation²⁶. AI has the potential to optimize the use of natural resources, improve energy efficiency in buildings and transport, support the management of smart energy grids, predict and mitigate the impacts of climate change, and promote the design of more sustainable products and processes²⁷. It can also be employed for environmental monitoring and simulations, emissions' data analysis, and promoting the circular economy through optimization of material flows and waste reduction²⁸.

Beyond operational optimization, AI also addresses one of the core challenges in environmental decision-making, that is the limitations of the precautionary principle²⁹. While traditionally used to justify regulatory caution in the face of uncertainty, this principle often leads to economically inefficient outcomes, prohibiting or heavily regulating specific activities. AI, through its ability to perform probabilistic modeling and scenario analysis, provides an alternative decision framework that balances environmental risks with innovation potential³⁰. This helps regulators and businesses to move beyond risk-aversion and the classical one-size-fits-all approach, towards an adaptive, evidence-based environmental governance.

Big data analytics further enhances this landscape by enabling the identi-

²⁴ European Parliament, *The impact of EU legislation in the area off digital and green transition, particularly on SMEs*, in europarl.europa.eu, 14 March 2025; M. Baumgart - B. Espinosa Apáez, *On the implementation of smart meters in the European Union: Legal considerations regarding privacy and personal data protection in times of the Twin Transitions*, in R. Leal-Arcas (ed.), *Research Handbook on EU Energy Law and Policy*, Cheltenham, 2024, 500 ss.; B. Garske - W. Holz - F. Ekdardt, *Digital twins in sustainable transition: exploring the role of EU data governance*, in frontiersin.org, 14 March 2025.

²⁵ KPMG, *ESG in the age of AI*, in assets.kpmg.com, 17 March 2025.

²⁶ OECD, *AI Compute & Climate Change*, in oecd.ai, 17 March 2025; R. Nishant - M. Kennedy - J. Corbett, *Artificial intelligence for sustainability: Challenges, opportunities, and research agenda*, in *International Journal of Information Management*, 53, 2020, 1 ss.

²⁷ K. Vieth-Ditlmann, *Sustainable AI: a contradiction in terms?*, in algorithmwatch.org, 24 March 2025; European Parliament, *AI for Sustainability – A Human-centric Approach to Global Challenges*, in futurium.eu.europa.eu, 17 march 2025.

²⁸ World Economic Forum, *9 ways AI is helping tackle climate change*, in weforum.org, 24 March 2025.

²⁹ G. Muto, *Is it possibile to go beyond the precautionary principle in climate change policy-making? AI as a tool for efficient decisions*, in medialaws.eu, 30 May 2025; R. B. Stewart, *Environmental regulatory decisions making under uncertainty*, in *Research in Law and Economics*, 20, 2002, 71 ss.; C. R. Sunstein, *Beyond the precautionary principle*, in *University of Pennsylvania Law Review*, 3, 2003, 1003 ss.

³⁰ G. Muto, *Is it possibile to go beyond the precautionary principle*, cit.

fication of patterns and inefficiencies across vast datasets. In the energy domain, for instance, this can provide valuable insights for understanding consumption patterns, identifying inefficiencies, optimizing production and distribution, and monitoring pollution³¹.

When integrated with geospatial and climate data, big data analytics also supports more precise environmental planning, from urban mobility to natural disaster resilience³². It enables real-time analysis of urbanization, air quality, land use and population dynamics, supporting the design of low-emission cities³³. In disaster risk management, it improves forecasting of extreme weather events like floods and heatwaves, informing early warning systems and emergency preparedness strategies³⁴. Additionally, such data-driven insights can guide post-disaster reconstruction by identifying the most resilient design strategies and the most affected zones³⁵. Big data also aids in biodiversity conservation and greenhouse gas emissions' tracking, ensuring better compliance with climate goals both at the local and national scale³⁶.

It is important to highlight that, in its decision-making, big data analytics can incorporate not only economic but also social dimensions, thus facilitating a more holistic approach to sustainability³⁷. This is particularly valuable as environmental issues often show complex trade-offs, that span different areas and catalyze strong partisan divisions³⁸. Higher levels of trust, transparency and public engagement can also be achieved thanks to a broader access to data, benefiting not just researchers but society as a whole³⁹. Citizens, NGOs and local communities can use this information to hold authorities accountable, contribute to local knowledge, and collaborate on sustainable intervention with a multistakeholder approach.

Besides AI and big data analytics, other emerging technologies, like Internet of Things (IoT) and blockchain, must be assessed for the purpose of this paper. IoT enables the collection of real-time data from a wide range of devices and sensors, providing a key tool for environmental monitoring, energy management, optimization of industrial processes, and imple-

³¹ OECD, *Understanding and Applying the Precautionary Principle in the Energy Transition*, in *oecd.org*, 30 May 2025.

³² UN Environmental Programme, *Can big data help protect the planet?*, in *unep.org*, 30 May 2025.

³³ E. Aloitaibi - N. Nassif, *Artificial intelligence in environmental monitoring: in-depth analysis*, in *Discover Artificial Intelligence*, 4, 2024, 1 ss.

³⁴ A. McGovern - R. J. Chase - M. Flora - D. Gagne - R. Lagerquist - C. K. Potvin - N. Snook - E. Loken, *A Review of Machine Learning for Convective Weather*, in *Artificial Intelligence for the Earth Systems*, 2, 2023, 1 ss.

³⁵ M. Yu - C. Yang - Y. Li, *Big Data in Natural Disaster Management: A Review*, in *Geosciences*, 5, 2018, 1 ss.

³⁶ UN Environmental Programme, *Can big data help protect the planet?*, cit.

³⁷ R. Dubey - A. Gunasekaran - S. J. Childe - T. Papadopoulos - S. Z. Luo - S. F. Wamba - D. Roubaud, *Can Big Data and Predictive Analytics Improve Social and Environmental Sustainability?*, in *Technological Forecasting and Social Change*, 1, 2017, 1 ss.

³⁸ D. Caldwell - G. Cohen - N. Vivyan, *Long-run trends in partisan polarization of climate policy-relevant attitudes across countries*, in *tandfonline.com*, 30 May 2025.

³⁹ OECD, *We need to use AI to right climate change*, in *oecd.ai*, 30 May 2025.

mentation of sustainable mobility solutions inside the so called “smart cities”⁴⁰.

Blockchain technologies, thanks to their decentralization and distribution, can ensure transparency and traceability in sustainable supply chains, facilitate peer-to-peer renewable energy trading and eliminate the need for inefficient intermediaries⁴¹.

4. ... and as a Barrier

Despite these potential transformative forces, the EU must address significant challenges and critical issues regarding digital technologies. The environmental footprint of digitalization is, in fact, substantial and growing proportionally with the energy demands of data centers, AI, and cloud computing⁴².

Some scholars have even shown that specific technologies, that are cloud computers, data centres and blockchain miners, are potentially more detrimental than beneficial to the twin transition since they need large amounts of energy and water to cool the infrastructures⁴³. In addition, data centres’ greenhouse gas emissions are very high and they occupy vast areas of land, potentially damaging the surrounding biodiversity and landscape⁴⁴.

This highlights the need for evidence-based policies and for a constant and close dialogue between academia and institutions, focusing on both the benefits and the potential negative effects of digitalization.

But the negative effects of digitalization are not limited to energy and water consumption, greenhouse gases, and land use. Digital devices’ supply chain, in fact, is based on raw materials, some of which are scarce or extracted with significant environmental and social impacts⁴⁵. Furthermore, electronic devices’ rapid obsolescence generates a growing volume of waste, posing significant challenges for recycling and hazardous materials’ management⁴⁶.

It is therefore evident, in the trilemma between fiscal stability, ecological transition and strategic autonomy, that the twin transition has profound implications for the labor market and for social equity, too. While digitalization can enhance productivity and create new opportunities, it also

⁴⁰ F. A. Almalki - S. H. Alsamhi - R. Sahal - J. Hassan - A. Hawbani - N. S. Rajput - A. Saif - J. Morgan - J. Breslin, *Green IoT for Eco-Friendly and Sustainable Smart Cities: Future Directions and Opportunities*, in *Mobile Networks and Applications*, 28, 2021, 178 ss.

⁴¹ G. B. Bhavana - R. Anand, *Applications of blockchain technology in peer-to-peer energy markets and green hydrogen supply chains: a topical review*, in *Scientific Reports*, 14, 2024, 1 ss.

⁴² S. Garsia, *The environmental costs of AI: a shake-up of the EU’s twin transition*, in *law.kuleuven.be*, 24 March 2025.

⁴³ M. O’Brien - H. Fingerhut, *Artificial intelligence technology behind ChatGPT was built in Iowa – with a lot of water*, in *apnews.com*, 24 March 2025; S. Gonzalez Monserrate, *The Staggering Ecological Impacts of Computation and the Cloud*, in *thereader.mitpress.mit.edu*, 24 March 2025.

⁴⁴ J. Roundy, *Assess the environmental impact of data centers*, in *techtargget.com*, 24 March 2025.

⁴⁵ *Ibid.*

⁴⁶ S. Gonzalez Monserrate, *The Staggering Ecological Impacts of Computation and the Cloud*, cit.

poses risks of automation and job displacement⁴⁷.

Ensuring a just transition necessitates proactive policies focused on education, digital skills' development, and social welfare systems to support workers in adapting to a changing labour market and reducing social inequalities.

Alongside these policies, policy-makers must obviously focus also on mitigating the environmental impact of digitalization, promoting digital infrastructures' energy efficiency, sustainable materials' use, durable and repairable products' design, and effective recycling and reuse systems, with a comprehensive and data-driven approach⁴⁸.

5. Is data *literally* the “new oil”?

Data represent a cornerstone for both the digital and ecological transitions⁴⁹. The availability of high-quality, granular, and accessible data is crucial for the development of smart energy services, accurate environmental monitoring, and rigorous scientific research⁵⁰.

The granularity of energy data has been identified as a barrier for more detailed data-driven analysis, limiting models' precision and the ability to provide effective real-time services⁵¹. Various types of energy data, including energy source, price data, and contractual information, are essential for accurate calculations, behavioral suggestions, and optimized management of energy consumption and production.

The accessibility and interoperability of data are crucial to fully leverage the potential of digital technologies in support of sustainability. The creation of online platforms and sandboxes for sharing environmental and energy data can surely facilitate the cooperation among policy-makers and improve transparency⁵².

In this regard, AI, data centres and blockchain' environmental impact must not be overlooked, so not to turn into reality the famous expression

⁴⁷ Eurofound, *Employment impact of digitalisation*, in eurofund.europa.eu, 24 March 2025; A. M. Santos - J. Barbero - S. Salotti - A. Conte, *Job creation and destruction in the digital age: Assessing heterogeneous effects across European Union countries*, in *Economic Modelling*, 126, 2023, 1 ss.

⁴⁸ B. Vermeulen - A. Pyka, *The Twin Digital and green Transition*, cit., 1 ss.; Z. Kovacic - C. Garcia Casanas - H. March, *The twin green and digital transition*, cit.; D. Diodato - E. Huerger - P. Monicada Paternò-Castello - F. Rentocchini - B. Timmermans, *Introduction to the special issue on “the twin (digital and green) transition”*, cit., 755 ss.

⁴⁹ European Parliament, *The impact of EU legislation in the area of digital and green transition*, cit.; M. Baumgart - B. Espinosa Apáez, *On the implementation of smart meters in the European Union*, cit., 500 ss.; B. Garske - W. Holz - F. Ekardt, *Digital twins in sustainable transition*, cit.

⁵⁰ Team, *The benefits of high-frequency granular data in sustainability reporting*, in teamenergy.com, 24 March 2025; A. Davé - P. Ball - K. Salonitis, *Factory Eco-Efficiency Modelling: Data Granularity and Performance Indicators*, in *Procedia Manufacturing*, 8, 2017, 479 ss.

⁵¹ *Ibid.*

⁵² W. Min Kwok, *Sandboxing and experimenting digital technologies for sustainable development*, in researchgate.net, 24 March 2025; A. Attrey - M. Leshner - C. Lomax, *The role of sandboxes in promoting flexibility and innovation in the digital age*, Paris, 2020.

«data is the new oil»⁵³ and to make data de facto comparable to fossil fuels' impact.

6. Policy and Governance of the Twin Transition in the EU

The EU has established a comprehensive set of policies and regulatory instruments to steer the twin transition and to ensure digital sustainability among all Member States.

The EGD provides the overarching framework for achieving climate neutrality and environmental sustainability, explicitly recognizing the driving role of digital technologies⁵⁴. The National Energy and Climate Plans (NECPs), introduced by Regulation (EU) 2018/1999, outline how Member States intend to address the five dimensions of the energy union, among which are decarbonisation and energy efficiency⁵⁵. Initiatives like the Digital Education Action Plan aim, for their part, to enhance digital literacy and to promote digital ecosystems' use in education⁵⁶.

Recent and more detailed regulations include the Digital Services Act (DSA) and the Digital Markets Act (DMA) that, while primarily focused on citizens' rights protection, digital fairness and competition, also have implications for sustainability. For instance, the emphasis on responsible design and online interfaces in art. 25 DSA can indirectly contribute to more sustainable consumption patterns among consumers⁵⁷. The reference made by arts. 34-35 DSA to systemic risks' mitigation by Very Large Online Platforms (VLOPs) and Very Large Online Search Engines (VLOSEs), the so called gatekeepers, could, in addition, require platforms to reduce their environmental impact⁵⁸.

Another recent EU regulation, the AI Act, includes several provisions to address the potential risks associated with AI technologies, fostering transparency and accessibility. Researchers, notably Zuzanna Warso and Kris Shrishak, have described these measures as «limited and inadequate ... to reduce the environmental impact of AI systems»⁵⁹. The adoption of codes of conduct and standards could, however, fill these loopholes thanks to a co-regulatory approach, involving all the stakeholders and con-

⁵³ European Parliament, *Is data the new oil? Competition issues in the digital economy*, in [europarl.europa.eu](https://europarl.europa.eu/en), 24 March 2025.

⁵⁴ European Commission, *The European Green Deal*, in [commission.europa.eu](https://commission.europa.eu/en), 24 March 2025.

⁵⁵ European Commission, *National energy and climate plans*, in [commission.europa.eu](https://commission.europa.eu/en), 24 March 2025.

⁵⁶ European Commission, *Digital Education Action Plan (2021-2027)*, in [education.ec.europa.eu](https://education.ec.europa.eu/en), 24 March 2025.

⁵⁷ European Commission, *The Digital Services Act package*, in [digital-strategy.ec.europa.eu](https://digital-strategy.ec.europa.eu/en), 26 March 2025.

⁵⁸ R. Griffin, *Climate Breakdown as a Systemic Risk in the Digital Services Act*, in bertie-school.org, 24 March 2025.

⁵⁹ Z. Warso - K. Shrishak, *Hope: The AI Act's Approach to Address the Environmental Impact of AI*, in techpolicy.press, 26 March 2025.

sumer organisations⁶⁰.

Data governance, standardization, interoperability, and cybersecurity are critical enablers of the ecological transformation⁶¹. This is why, in addition to the DSA, DMA and AI Act, the EU has developed a strong framework for data governance by introducing the Data Act, whose aim is to foster data ecosystems' environmental monitoring, resource management, and the development of circular economy solutions⁶². Challenges still remain in ensuring secure and ethical data access and sharing, while complying with privacy obligations.

Another important initiative in the EU context is the European Semester, EU's framework for economic policy coordination, as it is increasingly incorporating environmental sustainability considerations⁶³. Integrating social policy deeper into the European Semester could further enhance the focus on a just transition.

Financial instruments and funding programs, such as Horizon Europe, are also crucial for supporting research and innovation in areas relevant to the twin transition⁶⁴, while the Eco Design Directive, despite dating back to 2009, still plays a central role in driving digital and ecological transitions towards a common goal⁶⁵.

The Eco Design Directive, in particular, encourages manufacturers to improve products' environmental performance throughout their lifecycle, focusing on aspects such as energy efficiency, durability, recyclability, and reducing hazardous substances' use. Additional directives and initiatives, such as the Energy Labelling Directive, the European Union Ecolabel and the Design for Sustainability (D4S) Standards⁶⁶, can be followed by responsible manufacturers to complement the Eco Design Directive.

For fit-for-purpose businesses, the Corporate Sustainability Reporting Directive (CSRD) plays a crucial role, as it enhances corporate transparency and accountability regarding sustainability matters⁶⁷. Business are required to report detailed ESG information and reports must be standardized and verified by an independent auditor, as well as prepared in a machine-readable format. This makes it possible for information to be granular, accessible, and reusable for the aims of a data-driven EU environmental governance.

Lastly, the Corporate Sustainability Due Diligence Directive (CSDDD) is

⁶⁰ M. Cantero Gamito - C. T. Marsden, *Artificial intelligence co-regulation? The role of standards in the EU AI Act*, in *International Journal of Law and Information Technology*, 1, 2024, 1 ss.

⁶¹ European Parliament, *The impact of EU legislation in the area of digital and green transition*, cit.; M. Baumgart – B. Espinosa Apáez, *On the implementation of smart meters in the European Union*, cit., 500 ss.; B. Garske - W. Holz - F. Ekardt, *Digital twins in sustainable transition*, cit.

⁶² European Commission, *Data Act*, in *digital-strategy.ec.europa.eu*, 26 March 2025.

⁶³ European Commission, *The European Semester*, in *commission.europa.eu*, 26 March 2025.

⁶⁴ European Commission, *Horizon Europe*, in *research-and-innovation.ec.europa.eu*, 26 March 2025.

⁶⁵ European Commission, *Ecodesign and Energy Labelling*, in *single-market-economy.ec.europa.eu*, 26 March 2025.

⁶⁶ *Ibid.*

⁶⁷ European Commission, *Corporate sustainability reporting*, in *finance.ec.europa.eu*, 31 May 2025.

aimed at fostering sustainable and responsible corporate behaviour across companies' value chains, including the digital ones, specifically requiring large companies to publish regular reports on the social and environmental risks they face⁶⁸.

7. Circular Economy for a Digital Sustainable Future

Not considering the recent debates on CSDDD probable future delay or modification and the EU Commission apparent deregulatory shift⁶⁹, it is without any doubt that circular economy represents a prime example of the synergistic potential of the twin transition, and this justifies a focus on it in this paragraph⁷⁰.

In compliance with the aforementioned EU directives and initiatives, digital technologies can surely play an important role in shifting from a «take-make-dispose» model to a more sustainable system of «reuse, repair, recycle, and regeneration»⁷¹.

Firstly, data analytics and AI can inform eco-design by providing insights into product lifecycles, supply chains and material flows, facilitating the design of products that are more durable, repairable, and recyclable⁷².

Combined with Iot and big data, AI can improve resource management in manufacturing processes, optimize logistics, and enhance the transparency and sustainability of supply chains. AI and IoT can also optimize waste collection and sorting processes, increasing recycling rates and reducing landfill waste⁷³.

As mentioned above, digital product passports can provide comprehensive and easy-to-read information about a product's origin, composition, and lifecycle, enabling better tracking, reuse, and recycling⁷⁴.

However, realizing the full potential of digitalization for the circular economy requires addressing challenges such as the lack of interoperable solu-

⁶⁸ European Commission, *Corporate sustainability due diligence*, in commission.europa.eu, 26 March 2025.

⁶⁹ A. Alemanno, *The Dark Side of EU Deregulation*, in project-syndicate.org, 26 march 2025; H. Ruschemeier, *The De-Regulatory Turn of the EU Commission*, in verfassungsblog.de, 26 March 2025.

⁷⁰ B. Vermeulen - A. Pyka, *The Twin Digital and Green Transition*, cit., 1 ss.; Z. Kovacic - C. Garcia Casanas - H. March, *The twin green and digital transition*, cit.; D. Diodato - E. Huergo - P. Monicada Paternò-Castello - F. Rentocchini - B. Timmermans, *Introduction to the special issue on "the twin (digital and green) transition: handling the economic and social challenges"*, cit., 755 ss.

⁷¹ M. Antikainen - T. Uusitalo - P. Kivikyto-Reponen, *Digitalisation as an Enabler of Circular Economy*, in *Procedia CIRP*, 73, 2018, 45 ss.

⁷² OECD, *AI Compute & Climate Change*, cit.; R. Nishant - M. Kennedy - J. Corbett, *Artificial intelligence for sustainability*, cit., 1 ss.; World Economic Forum, *9 ways AI is helping tackle climate change*, cit.

⁷³ *Ibid.*

⁷⁴ European Data, *EU's Digital Product Passport*, cit.

tions and the need for standardized data protocols⁷⁵. Furthermore, business models need to evolve to incentivize circular practices and overcome existing obstacles to ecological transition in various sectors, starting from the clothing one.

E-commerce and B2C platforms, such as ASOS, Zalando, Vinted, are extremely popular among EU consumers, helping them to connect with repair services, facilitating second-hand markets and extending product lifespans⁷⁶. However, unsustainable manufacturing practices, low-quality textiles and poor working conditions are often associated with these businesses, making their regulation particularly challenging in light of their transnational structure⁷⁷.

8. Conclusion and Future Perspectives

The twin transition represents a pivotal moment for the EU. While the vision of a synergistic relationship between digitalization and ecological sustainability holds big promise, its realization requires a multidimensional effort, as exemplified by the EGD and the Draghi Report⁷⁸.

This paper has highlighted the various ways in which digital technologies can drive and contribute to the ecological transition, from enabling smart energy systems and promoting the circular economy to enhancing ESG reporting and fostering eco-innovation.

However, it has also been underscored the critical need to address the digital sector's inherent environmental impact and to proactively overcome its barriers, by managing the profound social and economic consequences of the ecological transformation⁷⁹.

Robust methodologies and policy frameworks must be developed to assess the environmental impact of digital technologies across various sectors and to ensure their responsible deployment for sustainability, including data governance, interoperability standards, and incentives for circular business models⁸⁰.

In addition to this, investments in research must be made to promote sustainable economic principles within the ICT sector across all Member States⁸¹. Interdisciplinary approaches must be adopted, integrating not just economic, environmental and technological perspectives on the twin transition, but also the social one.

A holistic and multifaceted understanding of the twin transition, by combining twin and just transitions together, guarantees a wide range of ben-

⁷⁵ M. Antikainen - T. Uusitalo - P. Kivikyto-Reponen, *Digitalisation as an Enabler of Circular Economy*, cit., 45 ss.

⁷⁶ UN, *E-commerce and environmental sustainability*, in *un-ilibrary.org*, 28 March 2025.

⁷⁷ *Ibid.*

⁷⁸ M. Draghi, *The Future of European competitiveness. Part A*, cit.

⁷⁹ M. Mandelli - S. Sabato - M. Jessuola, *EU Economic Governance and the Socio-Ecological Transition*, cit., 619 ss.

⁸⁰ *Ibid.*

⁸¹ M. Draghi, *The Future of European competitiveness. Part A*, cit.

efits for economy and society as a whole⁸². To this end, investments in education, skills development, and social safety nets are crucial to mitigate potential negative impacts on the labor market and to ensure social equity. By acknowledging these complexities and proactively addressing them, the EU can harness the transformative power of the twin transition to forge a more sustainable, competitive, and equitable future for all its citizens and to contribute to global efforts in addressing the urgent environmental challenges of our time.

Europe must not stifle new emerging ideas, but it must promote them and create a truly common and competitive market, securing strategic independence and enhancing its geopolitical influence. «Thus - with the words of Mario Draghi - we will build a strong and cohesive Europe, because each of its states is strong only if it is together with the others and only if it is cohesive within itself»⁸³.

⁸² S. Sabato - M. Mandelli - M. Jessuola, *Towards an EU eco-social agenda?*, cit., 199 ss.; S. Lange - L. Denick, *Digital Reset*, cit.

⁸³ Words have been extracted and translated by the author from Draghi's audition at the Italian Camera dei Deputati on 18 March 2025, see Camera dei Deputati, *Competitività europea, audizione Draghi*, in comunicazione.camera.it, 28 March 2025.

Abstract

This paper explores the European Union's strategic approach to the digital and ecological transitions, so called twin transition, as a key to ensuring long-term sustainability, competitiveness, and social equity. It shows the theoretical framework of the transition and subsequently analyzes how digital technologies, such as Artificial Intelligence and big data analytics, can act as powerful enablers of ecological sustainability. At the same time, the paper addresses the environmental and social costs associated with digital infrastructures, emphasizing the importance of specific regulatory frameworks to advance towards a more cohesive and resilient future. Environmental and digital laws are analyzed, focusing on the European Green Deal, Digital Services Act, Digital Markets Act, Corporate Sustainability Reporting Directive and other relevant initiatives. This makes it possible to understand how the EU can shift from a "take-make-dispose" model to a circular economy, solving the so called trilemma. De iure condendo, future perspectives are presented and assessed on the basis of the Draghi Report.

Keywords

twin transition – sustainability – digitalization - Artificial Intelligence - circular economy